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Producing Southern Pine Seedlings in Containers

James P. Barnett and John C. Brissette

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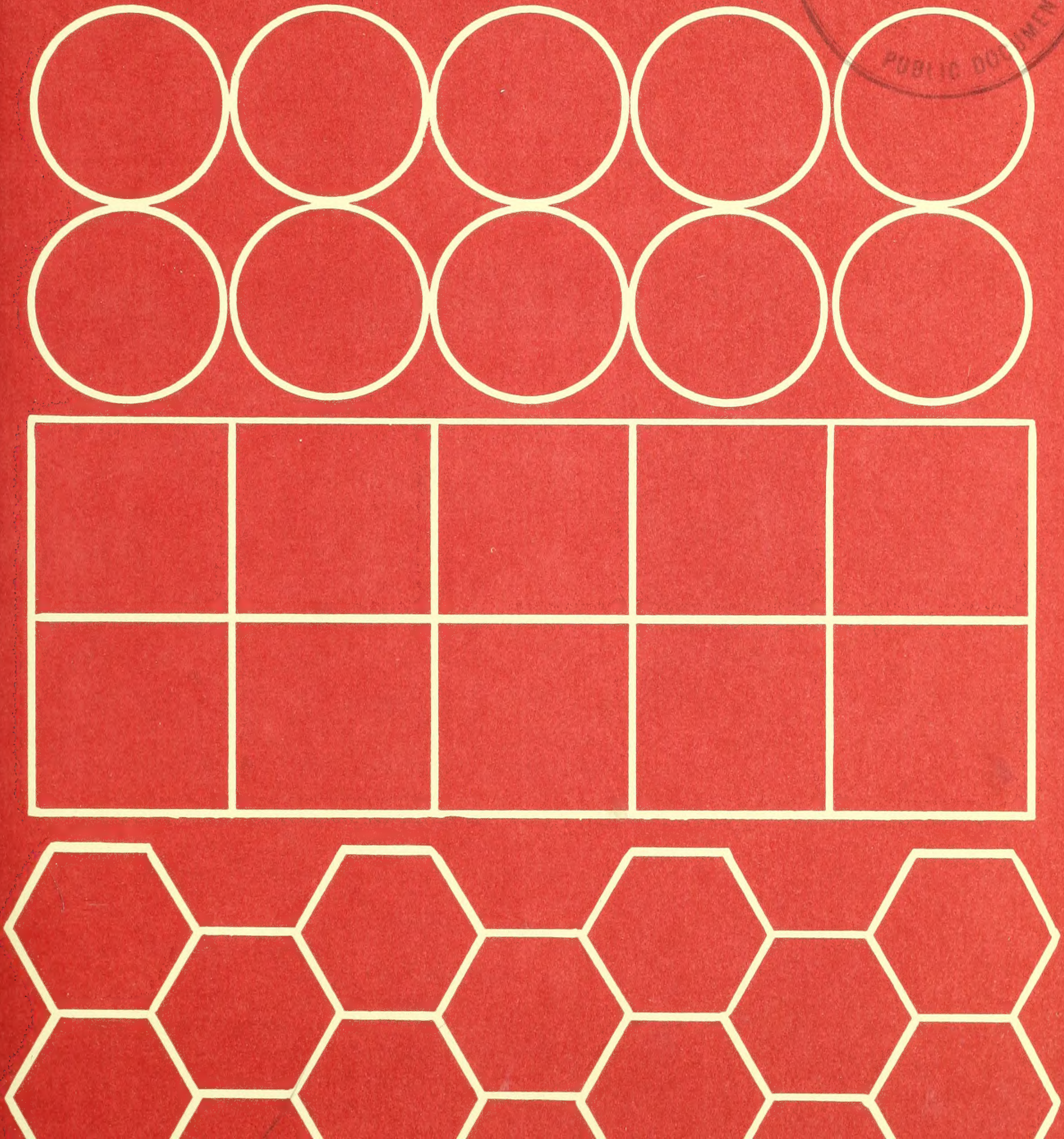

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Producing Southern Pine Seedlings in Containers

James P. Barnett and John C. Brissette

1. INTRODUCTION

Forest lands in the South are usually regenerated by planting bare-root seedlings, although natural or artificial seeding is used to a limited extent. Despite record tree planting levels in recent years, reestablishment of southern pine forests has fallen behind the harvesting effort. The use of container-grown seedlings, which has increased dramatically in the western United States and Canada in the last few years, offers land managers an alternative to traditional regeneration techniques. Containerized seedlings account for 20 percent of the total production of conifer planting stock grown in the Pacific Northwest. The use of container-grown seedlings is more limited in other parts of the United States, but as research shows the feasibility of the system in the South and other regions, its value as a supplement to bare-root seedling production is being acknowledged.

The purpose of this manual is to establish procedural guidelines for production of container-grown pine seedlings, particularly in the southern United States. These guidelines should be helpful in container production facilities already in existence and should be particularly beneficial to organizations contemplating or beginning container-grown seedling programs.

Guidelines now available are primarily for Canadian use (Matthews 1971, Ontario Dept. of Lands and Forests 1968, Kay 1973, Carlson 1979, Walker and Johnson 1980, Scarratt and others 1982). The manual published by the North Carolina Forest Service was prepared for use specifically in their own facilities (Goodwin 1975). “How to grow tree seedlings in containers in greenhouses,” by Tinus and McDonald (1979), provides an excellent overview of greenhouse facilities and growing procedures for the northern and western United States; much of it is also appropriate for the South. It should be reviewed before facilities are planned and be a basic reference for greenhouse operators and growers. Other publications that are valuable references for the production and use of containerized southern pine seedlings are the “Proceedings of the Southern Containerized Forest Tree Seedling Conference” edited by Guldin and Barnett (1982), and “Regeneration costs using container-grown southern pine seedlings” by Guldin (1983).

The guidelines offered in this publication, plus the publications by Guldin and Barnett (1982) and Guldin (1983), contain or reference most of what has been published to date about the development of container facilities for the South, the production of containerized southern pine seedlings, and the use and performance of container stock on a variety of planting sites.

The guidelines in this publication are organized into three broad topics: selecting facilities and equipment, growing high quality seedlings, and handling and planting container stock. The chapters are arranged chronologically from developing appropriate container nursery facilities to establishment practices for containerized seedlings. There is some overlap among chapters. For example, aspects of disease control are discussed both under seed handling and under seedling cultural techniques. Such overlap is necessary because many topics must be considered at different times throughout a seedling crop rotation. It is recognized that many of the recommendations given in these guidelines are provisional and will require modification as research and development continues in the southern United States.

2. MERITS OF CONTAINER PLANTING

Many of the advantages of using container-grown seedlings rather than bare-root stock have been discussed by various authors (Stein and others 1975, Tinus 1976, Mann 1977, Stein and Owston 1977, Hahn 1982a). Advantages and disadvantages most appropriate for conditions in the southern United States are listed in table 2-1.

Table 2-1.—*Advantages and disadvantages of container-grown southern pine seedlings*

Advantages	Disadvantages
Quickly produced	Require more attention while growing
Extended planting season	May cost more
Improve performance of some species	Bulky to handle
Perform well on adverse sites	May require more intense site preparation
Efficient use of limited seed	Smaller size
Uniform seedlings	

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Containerized southern pine seedlings can be produced quickly. Loblolly pine (*Pinus taeda* L.) and slash pine (*P. elliottii* Engelm.) can be grown to plantable size in 12 to 14 weeks. Longleaf pine (*P. palustris* Mill.) can be produced in about 16 weeks. Such rapid production allows seedlings to be produced and fall planted in years when spring survival checks indicate replanting will be necessary. Similarly, genetic tests can be produced and outplanted the spring after seed collection. In both cases a year is saved compared to bare-root methods. Flexibility in production is also possible because containerized seedlings can be planted throughout an extended planting season, provided soil moisture and climatic conditions are favorable for growth. Bare-root longleaf pine seedlings tend to have poorer survival and initial growth than the other southern pines, probably because of the severe root disturbance caused by lifting. Containerized longleaf pine, with intact root systems, can have better survival and begin height growth sooner than bare-root stock (Goodwin 1980, Amidon and others 1982). Container-grown seedlings tend to perform better on adverse sites than do bare-root seedlings. In some cases container-grown seedlings may be the only way to successfully reclaim severely damaged sites such as mine spoils or to establish seedlings under droughty conditions as in shelterbelts. Because growing conditions can be better controlled, container planting offers increased seed efficiency, i.e., plantable seedlings to filled seeds ratio. When combined with rigid control of seedling density and root configuration, uniform stock will be produced, which can then be utilized in automated handling and planting systems.

There are, however, some disadvantages to the production and use of container-grown seedlings (Stein and Owston 1975, Barnett 1978a). Because of the relatively small volume of growing medium, the technique requires more demanding day-to-day attention to moisture and temperature regimes than is required for producing bare-root stock. The conditions that hasten containerized seedling development are also conducive to disease, nutritional imbalances, and other problems. Trees produced in containers will likely cost more than bare-root stock from existing, depreciated nurseries, but not necessarily more than seedlings from a new bare-root nursery (Guldin 1983). It has not been conclusively established that any extra cost will be fully offset by reductions in planting costs or gains in survival and early growth. Container-grown seedlings are bulkier to transport and must be handled differently from bare-root seedlings (see chapter 12). On sites with severe herbaceous competition, more complete site preparation may be necessary for success with containerized seedlings because of their smaller initial size (Ruehle and others 1981).

3. COMPARATIVE PERFORMANCE

Although there are biological and production a vantages to be realized from growing seedlings in co tainers, the key to success depends on field perforn ance. There are few good comparative trials. Wester conifer containerized seedlings usually equal or e ceed survival of bare-root nursery stock (Tinus 197 Stein and Owston 1977, Arnott 1981, Hahn and Smi 1983, Gardner 1982, Vyse 1982). In eastern Canad results with northern conifers indicate that paperpo grown containerized seedlings survive better b have a growth lag when compared to larger bare-ro stock (Krause 1982, Mattice 1982, Scarratt 1982).

In the South, survival has generally exceeded th of nursery stock, and growth comparisons are go (Goodwin 1976, Barnett 1975, 1980a). Contain stock clearly outperforms nursery seedlings when a from seed is considered (Goodwin 1976). Compariso of container-grown and nursery seedlings that a outplanted at the same time indicate that containe grown seedlings can perform as well or better wh high-quality stock is used. Goodwin (1980) found th after five growing seasons, containerized longle pine seedlings survived better and grew faster th 1+0 nursery seedlings when planted on sandhill site He concluded that containerized longleaf seedlin can be used to extend the normal planting season a to replant 1+0 seedling failures in the same growi season if there is sufficient soil moisture.

Data comparing regeneration methods with loblo and slash pine indicate that containerized seedlin planted in the late spring or early summer ha growth comparable to bare-root seedlings plant during the preceding winter (table 3-1). These resu are not unique, but reflect frequent observations (B nett 1980a).

Amidon and others (1982) report that und droughty conditions container-grown seedlings su vived and grew better than nursery stock when t containerized seedlings were outplanted in the la summer before the normal bare-root planting seas Even under severe moisture stress, container-grow seedlings performed better than bare-root seedlin when outplanted at the same time in early spring

Table 3-1.—*Container-grown and bare-root seedling performa after 3 years*[1]

Stock type	Loblolly pine		Slash pine	
	Height	Diameter	Height	Diame
	m	*cm*	*m*	*cm*
Container (12-weeks old)	0.84	1.45	0.91	1.7
Bare-root (1+0)	0.82	1.24	0.98	1.8

[1]Bare-root stock planted in Feb. 1978; containerized seedli planted in late May 1978.

4. FACILITIES FOR SEEDLING PRODUCTION

4.1 Site Selection

Site selection criteria for container nursery facilities are much less stringent than for a new bare-root nursery. Topography and soil constraints that may prohibit the development of a bare-root nursery would not influence construction of a container facility. Considerations that are important when selecting a site for a container nursery include: management objectives, location of planting sites, climate, water supply and quality, road access and utilities, labor supply, and proximity to mills and other manufacturing facilities. Hahn (1982b) provides some valuable insights into these and other considerations of site selection.

4.1.1 *Management Objectives*—The actual area needed to develop a container nursery will depend on the present and anticipated future demand, the type of container used, and the number of seedling rotations that can be produced annually. Annual production from each 319 m^2 (3,425 ft^2) of growing space will vary from 330 thousand to 1,890 thousand seedlings in one to three crop rotations, depending on the facility and container (Guldin 1982). Obviously, many factors must be considered before an accurate determination of the needed area can be made. The single most important factor is the container used, and containers are discussed in detail in chapter 5. Other important factors are discussed in the following sections.

4.1.2 *Location of Planting Sites*—Container-grown seedlings are bulky, so the growing facility should be located centrally to the intended planting sites to minimize transportation costs. Shipping costs per 1,000 seedlings are equal for container and bare-root stock for distances up to 161 km (100 miles), provided the containers are shipped on pallets fitted with racks (Guldin 1983). Extracting containerized seedlings before shipment can also reduce bulk and costs but certain precautions must be followed (see section 12.2).

4.1.3 *Climate*—The geographic location of a container nursery will largely determine what type of structures and facilities will be required. The South has been divided into three climatic zones, based on length of the frost-free growing period and how long during this period daily maximum temperatures exceed 32 °C (90 °F) (Guldin 1983) (table 4-1 and fig. 4-1). These climatic variables, combined with management objectives, will determine the degree of environmental control needed and the number of rotations that can be produced annually. In facilities with minimum environmental controls or none, both the length of the frost-free growing season and the likelihood of temperatures above 32 °C (90 °F) will restrict the period of optimum seedling growth. Therefore, with minimum environmental control, it may be possible to start crops both in the spring and fall in Zone A, but in Zones B and C it is likely that only one crop would be produced annually. With increasing control over the seedling growing environment, the climatic factors become less important, but energy needs, and consequently production costs, rise.

Table 4-1.—*Climatic zones for containerized seedling production and planting (from Guldin 1983)*

Climatic factor	Climatic zone A	Climatic zone B	Climatic zone C
Date of last spring frost	February 20 to March 10	March 20 to 30	April 10 to 20
Period when daily air temperature exceeds 32 °C[1]	More than 90 days (June 1 to September 15)	60–90 days (June 1 to September 7)	30–60 days (June 15 to September 1)
Date of first fall frost	November 20 to December 10	October 30 to November 10	October 20 to 30

[1] 90 °F

4.1.4 *Water Supply*—An adequate and dependable supply of water for irrigation is essential for producing containerized seedlings. Approximately 16 to 20 liters per hour per square meter of growing area (0.4–0.5 gal/hr/ft^2) is needed to adequately water 20 cm (8 in) deep containers (Tinus and McDonald 1979). If the facility is used year-round, this will be equal to an annual water need of 1,222 to 1,630 liters per square meter of growing space (30–40 gals/ft^2). Additional water will be needed for domestic, and possibly cooling, needs. Detailed information for calculating total water and water rate needs is provided in Tinus and McDonald (1979). The quality of water available for irrigation is an essential part of site selection. Because implications of water quality go beyond site selection, this topic is covered in detail in section 4.2.

4.1.5 *Other Considerations*—Road access and availability of utility services need to be considered when selecting container nursery sites. Larger facilities require better road access than small facilities because of the size of vehicles that will make deliveries and pickups. Utility needs depend primarily on heating and cooling requirements. The availability of a local labor supply, especially a temporary force during peak periods, must be considered. The proximity of the container nursery to wood processing and other manufacturing plants can impact seedling production. Mills and woodyards may harbor potential seedling pests such as pales weevil (*Hylobius pales* Herbst.), and some manufacturing plants may emit pollutants that can adversely affect seedling growth.

4.2 Water Quality

Irrigation water quality is a critical factor in management of container growing facilities. The definition of water quality depends on its use, but for agri-

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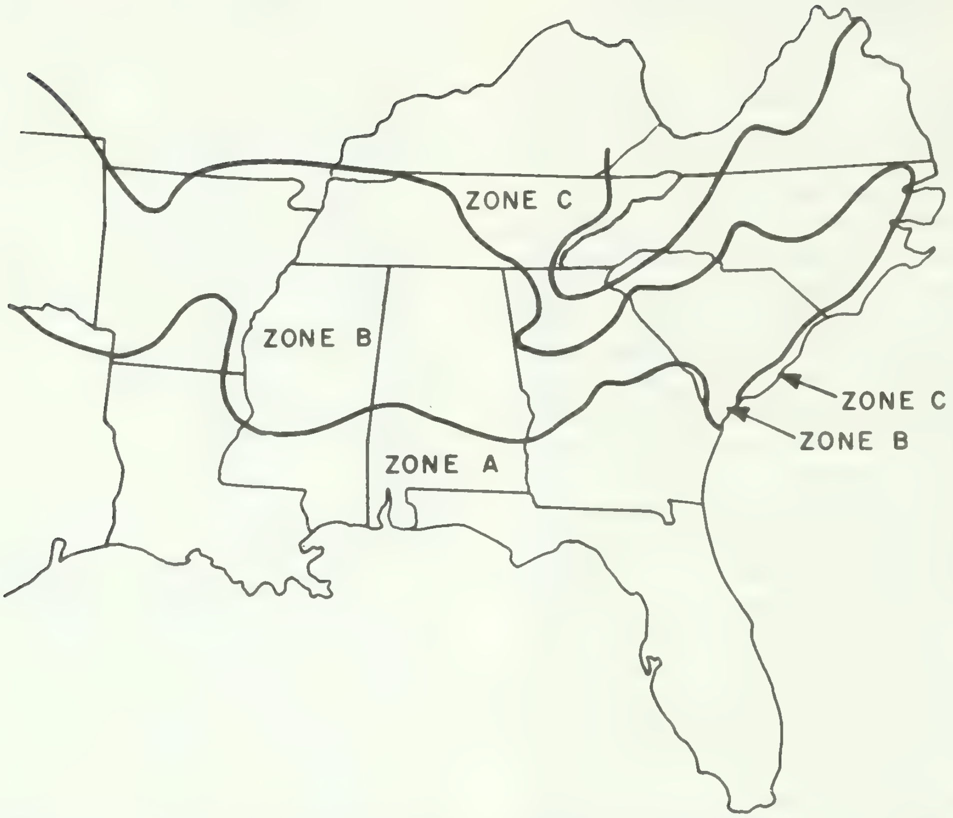


Figure 4-1.—*Climatic zones for southern pine container-grown seedling production (from Guldin 1983).*

cultural purposes, the concentration and composition of dissolved salts determine its value for irrigation (Landis 1982). All plants are susceptible to salt injury under certain conditions, but tree seedlings, conifers in particular, are very sensitive to soluble salts. Levels of dissolved salts high enough to cause concern are rare in the Southeast, but salinity problems can develop in containerized seedling operations when irrigation and fertilization are improperly applied. Water quality can be a problem along the western edge of the southern pine ecotype.

Soluble salts can cause injury to containerized seedlings in several ways: 1) by reducing moisture availability, 2) through direct toxicity, and 3) by altering nutrient availability (Fuller and Halderman 1975, Landis 1982).

The total concentration of dissolved salts in irrigation water is generally expressed as electrical conductivity, which is measured in units of conductance (micromhos/cm) at a standard temperature (25 °C, 77 °F). Dissolved salts decrease the free energy of water molecules and reduce their availability to plants. This osmotic inhibition is a function of total salts regardless of the specific ions.

The salinity hazard has been divided into four ratings based on observed effects on plant growth (table 4-2). The salinity of irrigation water is not a true index of salt damage, however, because plants respond to salt concentrations in the soil solution. Salt levels in the root zone are typically many times as concentrated as in the water supply.

Three ions have been observed to directly injure plant tissue; sodium, chloride, and boron. Sodium and chloride can be absorbed either through the foliage or by the root system. Boron must normally come from the soil. Foliage injury is particularly severe under sprinkler irrigation systems. In general, trees and other woody perennials are sensitive to rather low concentrations of sodium and chloride compared to annual crops. Boron toxicity is hard to predict because the range between beneficial and toxic concentrations is narrow for some plants (Eaton 1966).

Saline irrigation water can also change the availability and utilization of plant nutrients. This effect is particularly difficult to define because of the complicated chemical interactions in soil chemistry and

Table 4-2.—*Salinity hazard ratings*

Rating[1]	Electrical conductivity
	(micromhos/cm)
Low	250
Medium	250–750
High	750–2250
Very High	2250

[1] USDA Salinity Lab (1969).

seedling physiology. Excess calcium can chemically immobilize phosphorus and inhibit uptake by plants. Iron chlorosis is a complex nutritional disorder of woody plants and has been associated with an abnormal accumulation of salt ions in conifer seedling foliage.

Irrigation water quality is rarely the sole cause of salinity problems but rather one in a series of interacting conditions. Other factors such as media drainage, irrigation method, cultural practices, climatic conditions, and crop salt tolerance are equally important. A nursery manager must consider all these factors before designing an irrigation program, and this becomes increasingly more important as water salinity increases (Landis 1982).

Water quality and its effects on seedling growth and development can be much more easily managed in a container nursery than in a bare-root nursery. Although salt ion removal is still uneconomical for irrigation water, the effects of these ions can be reduced by controlling water pH and by leaching the growing medium at intervals. In many locations, water pH is higher than desired for optimum germination and growth. Water pH of 7.5 to 8.0 is not uncommon but it can be acidified and lowered to more optimum levels. Acidification procedures to reduce irrigation water pH are discussed in section 9.5. In addition, container potting medium can be mixed for maximum permeability, thus reducing the likelihood of salt accumulation. Vermiculite, perlite, and other coarse materials can be used to generate pore space in the growing medium. Chapter 6 discusses the selection and preparation of growing media.

However, there are some inherent dangers in container seedling production that relate to irrigation water quality. Because of the large amount of irrigation water used in most greenhouses, there is a real potential for salt accumulation in the potting soil. This danger is amplified when nutrients are injected into irrigation water, because fertilizer salts add to the total salinity level (see section 9.5.3). The only solution is to insure that excess salts are leached from the potting soil during each irrigation by watering until leachate drains out the bottom of the container (see section 9.5.3). The best control for saline water problems is to minimize them in the first place by a comprehensive examination of water quality.

4.3 Structures

Structures for growing containerized seedlings in the South may vary from simple shadehouses (fig. 4-2) to elaborate glass greenhouses (fig. 4-3). The type used depends on the management objectives for the facility. Biological, climatic, economic, and operational factors must be considered in deciding what kind of tree growing facility to construct. The economics of various facility, container type, and climatic zone combinations of containerized operations are compared to bare-root nursery production by Guldin (1983). His analyses indicate that container nurseries utilizing structures with limited environmental control and various container types and climatic zone

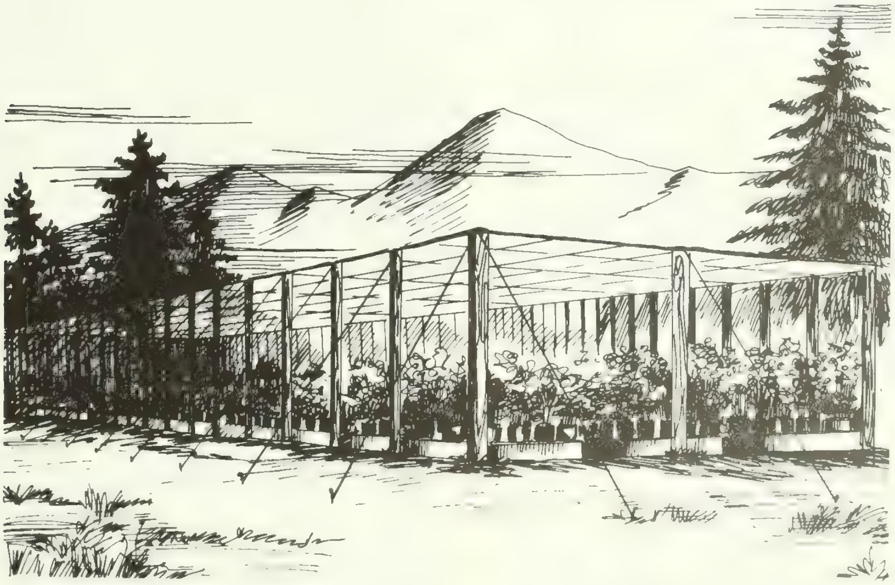


Figure 4-2.—*A simple shadehouse suitable for production of containerized southern pines during much of the year and for seedling hardening during the fall and winter (from Guldin 1983).*

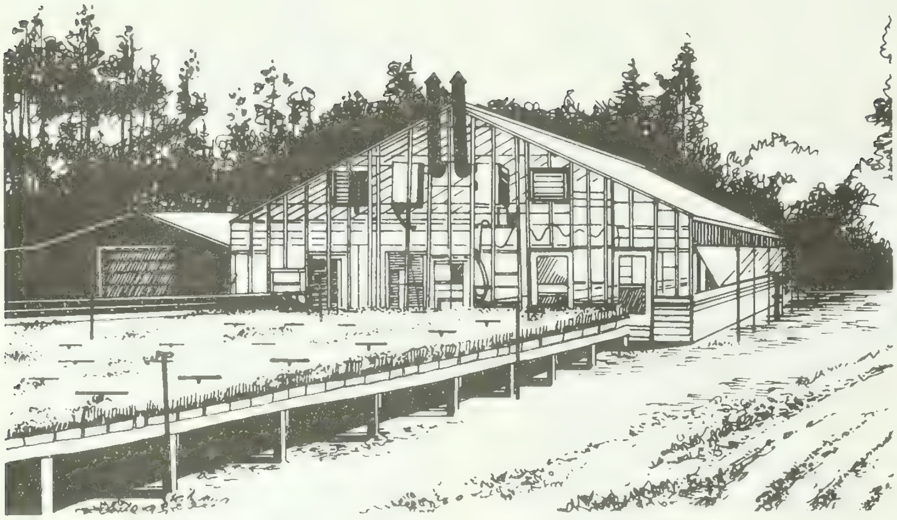


Figure 4-3.—*A more elaborate glass greenhouse with environmental controls suitable for containerized seedling production throughout the year (from Guldin 1983).*

combinations can give an annual production of at least 3 to 4 million seedlings. McDonald (1982) provides a valuable discussion of the relative merits of fully controlled and semicontrolled environment greenhouses. Generally, semicontrolled greenhouses are adequate in the Coastal Plain areas of the southern United States (zones A and B, fig. 4-1). However, if crops are to be produced over winter, a structure sufficiently controlled to provide adequate heating would be required. Temperature requirements for seedling germination and growth are discussed in sections 8.1.3, 8.2.3, and 9.1.2.

The design of seedling growing facilities is beyond the scope of these guides. Greenhouse design is covered adequately in other publications (Ekblad 1973, Kelsoe 1975, Husely 1973, Tinus and McDonald 1979, Cameron 1982, Siemens 1982). Hahn (1982b) provides some practical guidelines for developing containerized seedling facilities and operational programs. The environmental conditions necessary for optimum germination and seedling development, regardless of the growing facility, are discussed in chapter 8.

5. CONTAINERS

5.1 Developments in the Use of Containers

Isolated references to ball or container planting go back to 1725 (Toman and Hocking 1973), but McLean's (1959) more recent use of the Ontario tube seemed to stimulate development of the idea in North America. The great impetus for container planting resulted from Walters' publication of his technique based on the plastic bullet and planting gun in 1961 (Walters 1961). Jones (1967) reported early evaluations of seedlings grown in kraft-paper containers in the South. Since these early beginnings, a host of container materials have emerged for potential forestry use. Many of these have been developed primarily for northern and western situations. Included are products such as plastic bullets, Ontario tubes, BC/CFS Styroblocks®, Rootrainers®, extruded peat cylinders, Japanese Paperpots®, Ray Leach Single Cells®, plastic-mesh tubes, and wood-fiber blocks (Waldron 1972; Tinus and others 1974). Most of these products have been evaluated in the South (Barnett 1974b). In addition, kraft-paper tubes, polyurethane foam blocks, biodegradable plastic tubes, and peat-vermiculite blocks have been developed primarily for southern use (Barnett 1974a, Barnett and McGilvary 1981).

5.2 Types of Containers

The many container products can be divided into three general types: tubes, plugs, and blocks (fig. 5-1). Each type has certain merits that must be considered before a container system is selected.

5.2.1 *Tubes*—These containers have an exterior wall, require filling with a growing medium, and the seedlings remain in the container for outplanting. The primary advantage of tubes is wall rigidity, providing both ease of handling as well as sufficient impermeability to prevent desiccation when planted

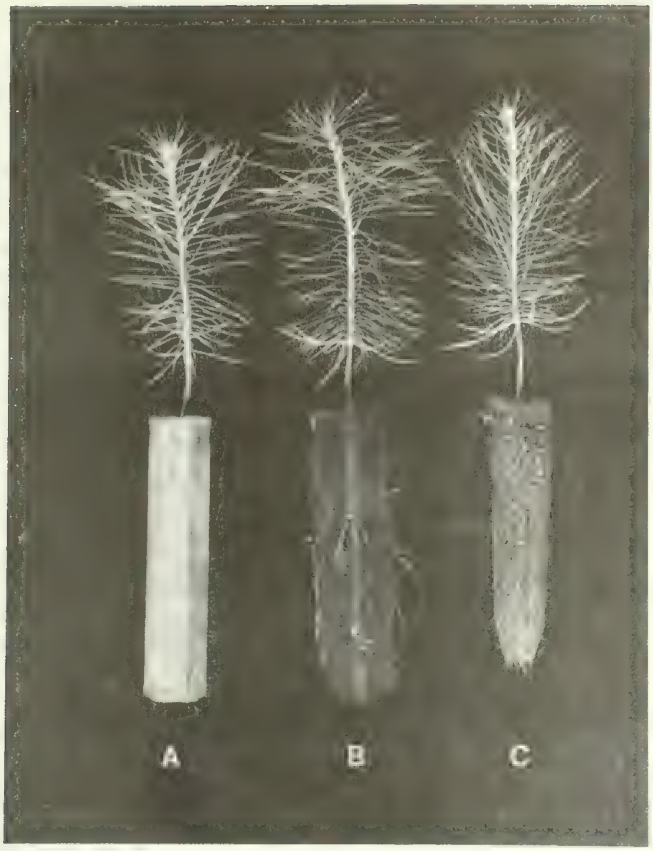


Figure 5-1.—*Loblolly pine seedlings grown in three types of containers: a biodegradeable plastic tube (A), a peat moss-vermiculite molded block (B), and a plug from Styroblock 2 (C).*

in dry soil (Day and Cary 1974). The major disadvantage of tubes is slow egress of roots into the soil because initial contact with the soil is made primarily through the bottom of the container. Based on evaluations of performance with the southern pines and on commercial availability, the Paperpot is probably the best tube-type container now available (Barnett 1981). The Japanese Paperpot does not degrade rapidly enough to allow satisfactory survival and growth. The Finnish Paperpot material now available is reportedly manufactured of material that allows faster root egress. But this leads to root penetration during the greenhouse growing period. Therefore, only small trees or short rotations are possible without root growth between containers and subsequent damage during extraction. Root spiraling also is a problem (Barnett and McGilvary 1981). Because of problems with tube-type containers, particularly under stress conditions, plug systems have generally replaced tube materials.

5.2.2 *Plugs*—Plugs are molded blocks that have a cavity filled with potting medium. They are the preferred container for operational use in the Pacific Northwest and Canada. But, unlike tubes or blocks, (see section 5.2.3), the seedlings must be removed from their containers before outplanting. The rooted seedlings, along with the growing media, are planted. Plugs provide an ideal biological setting for the seedlings, since no root constraint occurs after planting, and roots rapidly establish themselves in the surrounding soil. However, the seedlings must be held in the container long enough for the root to bind the soil to facilitate extraction. The length of time varies with the size of the container cavity and species of tree; generally the minimum is 3 to 5 months. A number of containers can be used to produce excellent plug seedlings. Examples are RL Single Cells, Rootrainers, and Styroblocks.

The BC/CFS Styroblock was developed in Canada to overcome root configuration problems inherent with plastic bullets. Seedlings grown in Styroblocks perform well when compared to those in other types of containers. Growth of slash pine seedlings after outplanting from several different containers showed that those from the Styroblock-2 (2 cubic-inch volume) equaled or exceeded all others except Keyes Peat Sticks®, discussed under block containers (table 5-1).

Other plug systems have the advantages of plug-type containers and perform well. Each specific container has certain characteristics that make it unique. The RL Single Cells can be handled individually for randomization of progeny-test material, removal of blanks, and transport. Rootrainers open to allow inspection of the root system and easy removal of the plug. The Todd Planter Flat® cavities are square, of obtuse taper for easy seedling extraction, and have lower numbers of seedlings per unit area in relation to cavity volume than most other container systems. The importance of seedling density is discussed in detail in section 5.3. There are no great differences in field performance of plug-type containers. Most of the variations in performance are more of a reflection of cavities per unit area, or seedling density, than container per se. Although plugs are easily planted by hand or conventional planting machines, adaptation to automated planting operations may be difficult.

5.2.3 *Blocks*—Block designs incorporate advantages of both tubes and plugs. The block itself is both the container and the growing medium. Seeds are sown in the block and the entire package is transplanted into the soil. Blocks are usually rigid enough for mechanized planting but still allow rapid root egress upon outplanting.

Although numerous block-type products have been evaluated, only a few have been available for use in large-scale programs. One type of self-contained container consists of acrylonitrile-bonded softwood pulp (Schneider and others 1970, White and Schneider 1972). This product, originally manufactured by American Can Company under the trade name of BR-

Table 5-1.—*Survival and heights of slash pine (*Pinus elliottii*) seedlings grown in various container products 1 + years after outplanting*[1]

Container	Survival			Height		
	4–26–74[2]	6–25–74	8–28–74	4–26–74	6–25–74	8–28–74
	----------- *percent* -----------			------------- *cm* -------------		
Gro-block	69	57	89	73	49	40
Peat stick	91	94	100	98	55	52
Paperpot (315)	81	76	96	64	46	46
Syroblock-2	89	93	98	76	49	43
Rootrainer (Ferdinand)	83	71	98	82	49	43

[1]Survival and height measurements taken in January 1976.

[2]This row gives planting dates.

8®, was later made by Famco, Inc., and called Gro-block®. Gro-blocks are not now commercially available. Although young seedlings (6 weeks old) grown in these blocks performed well when outplanted (Barnett 1975), older seedlings generally showed poorer survival and growth than seedlings of the same age growing in other containers. This poorer performance probably reflects the small volume of these Gro-blocks when compared to the other products tested. Further developmental work, such as increasing the size and ease of separation, is needed before the system is a viable one.

Probably the most promising block-type container evaluated has been developed by Keyes Fibre Company. The block consists of a blend of sphagnum peat moss, vermiculite, cellulose fibers, and nutrients. An early design of this product was rectangular in cross-section (2.8 by 3.2 cm or 1$^1/_8$ by 1$^1/_4$ in) and 15 cm (6 in) long. This block, termed a "Peat Stick" was used in several studies with good results (table 5-1). Loblolly and slash pine seedlings grown for 10 weeks in this block survived and grew better than those in other containers, particularly when outplanted under conditions of moisture stress (figs. 5-2 and 5-3).

High survival was maintained even following planting in June, July, and August, when survival of seedlings grown in Gro-blocks and Paperpots dropped. Heights of seedlings outplanted in Peat Sticks in June compared favorably to those of bare-root seedlings planted in the previous March.

Because of the success with Peat Sticks, the product was redesigned to provide for easier handling, packaging, and outplanting. The resulting Kys-Tree-Start® has a smaller volume, but has the same properties. The advantages of the Kys-Tree-Start include: (1) simplified greenhouse operations because no filling is required, (2) no root manipulation into undesirable patterns or constraint after outplanting, and (3) adaptability to mechanized planting equipment. After outplanting, root egress occurs from the entire block surface, and no unusual patterns of root development are evident that might cause future problems in seedling growth or stability (fig. 5-4). The blocks are subject to development of a saprophytic mold during the early greenhouse period and some root cross-over occurs along the back of the 10-block strip if seedlings are held for long periods. Some further development could make this an excellent product, but at the present time insufficient demand exists to keep this product commercially available.

5.2.4 *Other Containers*—Numerous container materials other than those described have been evaluated with the southern pines (table 5-2). Some of these have promise but for some reason have not been produced for commercial use. Our experience with a wide range of containers should provide the information necessary to anticipate the performance of other containers not reported here.

5.3 Container Size

There is a wide range of container sizes available; however, most in operational use have volumes of 40 to 165 cm^3 (2.5 to 10 in^3). Optimum size probably varies according to container characteristics, species, soil type, site preparation, and length of the growing period (Barnett 1974d).

A 10- to 12-cm (4- to 5-in) length is generally satisfactory for the southern pines. Diameters of 2.5 to 3.0 cm (1.0 to 1.25 in) seem minimal (Barnett 1974b). Recent studies have shown that container volume is less critical than seedling density (number per unit area). Figure 5-5 indicates some interaction between volume and density. Although Todd Planter Flats® had 25 percent less volume, seedling dry weights at time of outplanting were about twice as heavy in the Todd Planter compared to Japanese Paperpots. This difference in seedling condition resulted primarily from the much smaller number of seedlings grown per unit of area—312/m^2 (29/ft^2) for Todd Planters vs. 1,657/m^2 (154/ft^2) for Japanese Paperpots. The larger seedlings performed better in the field. In fact, seedling development even in the small Todd Planter cavities, both in the greenhouse and field, was better

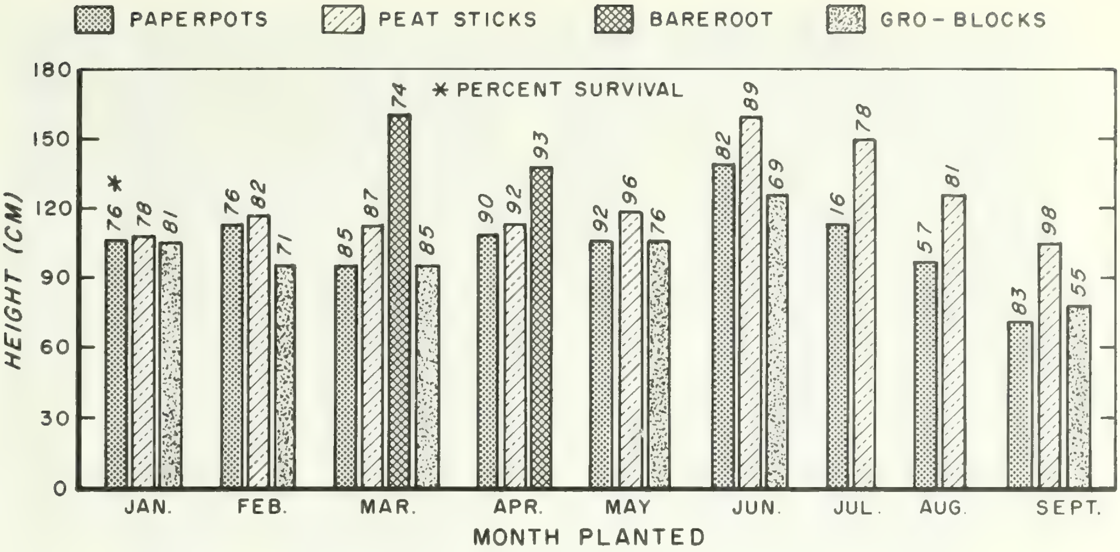


Figure 5-2.—*Heights and survival of loblolly pine seedlings outplanted in 1973; survival and growth measured in January 1976.*

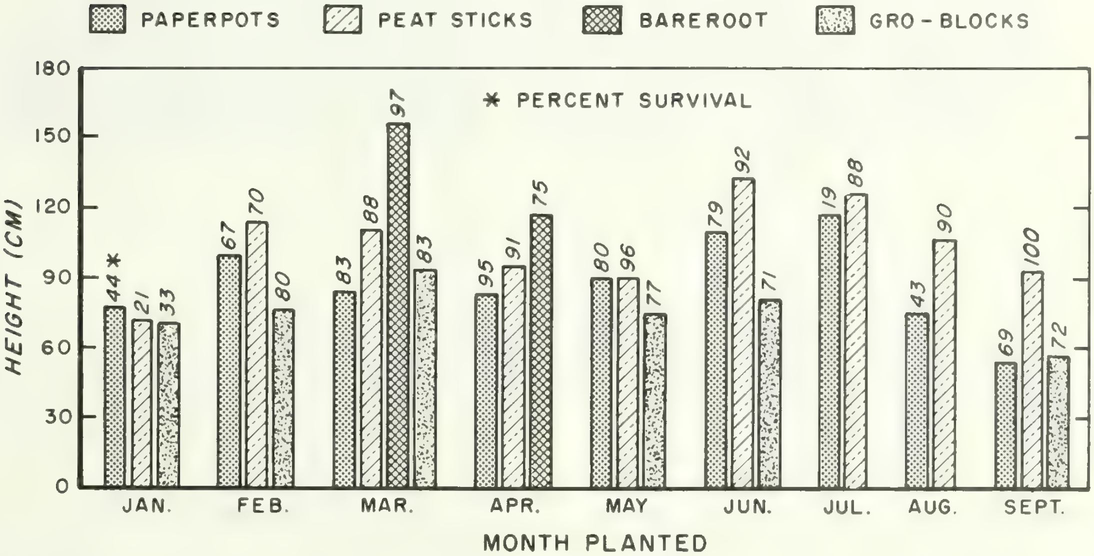


Figure 5-3.—*Heights and survival of slash pine seedlings outplanted in 1973; survival and growth measured in January 1976.*

than in Japanese Paperpots. The volume of the small Todd Planter was only 25 cm^3 (1.5 in^3) compared to 88 cm^3 (5.3 in^3) for the Japanese Paperpots. The initial seedling development is largely due to lower numbers of seedlings per unit of area.

The effects of seedling density during the greenhouse growing period become clearer when container volume remains constant. The period that seedlings are grown in containers also interacts with seedling density (fig. 5-6). If growing periods are limited to 8 to 10 weeks, spacing has less effect on seedling development than if larger seedlings are being grown. Densities exceeding about 1,075/m^2 (100/ft^2) reduce initial development and the resulting field performance of the southern pines. Although lowering seedling densities may continue to improve development and performance, factors such as the cost of greenhouse space will also influence the choice of container size and seedling density.

The species grown can also influence the relationship of container size and seedling density to performance. For example, longleaf pine, which is very intolerant, increases markedly in development when grown in larger-volume containers with lower spac-

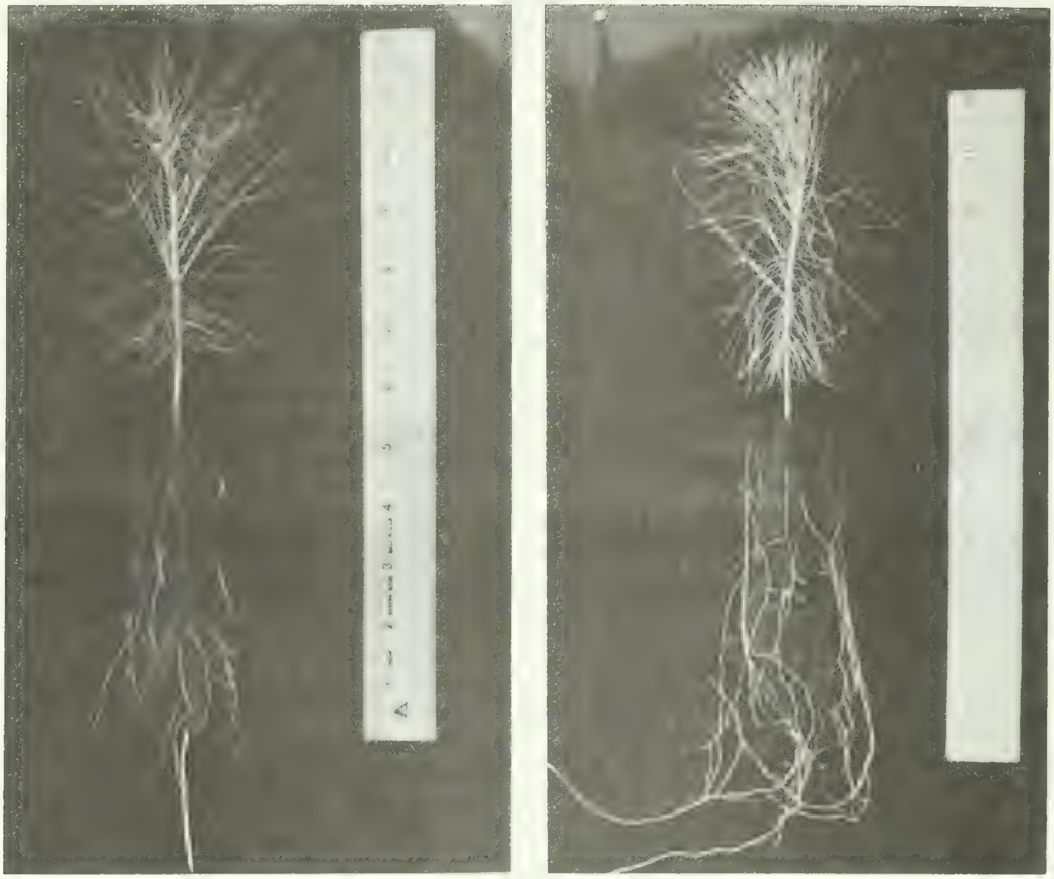


Figure 5-4.—*Development of loblolly pine seedlings in Kys-Tree-Starts 2 weeks (A) and 4 weeks (B) after outplanting into a sawdust bin.*

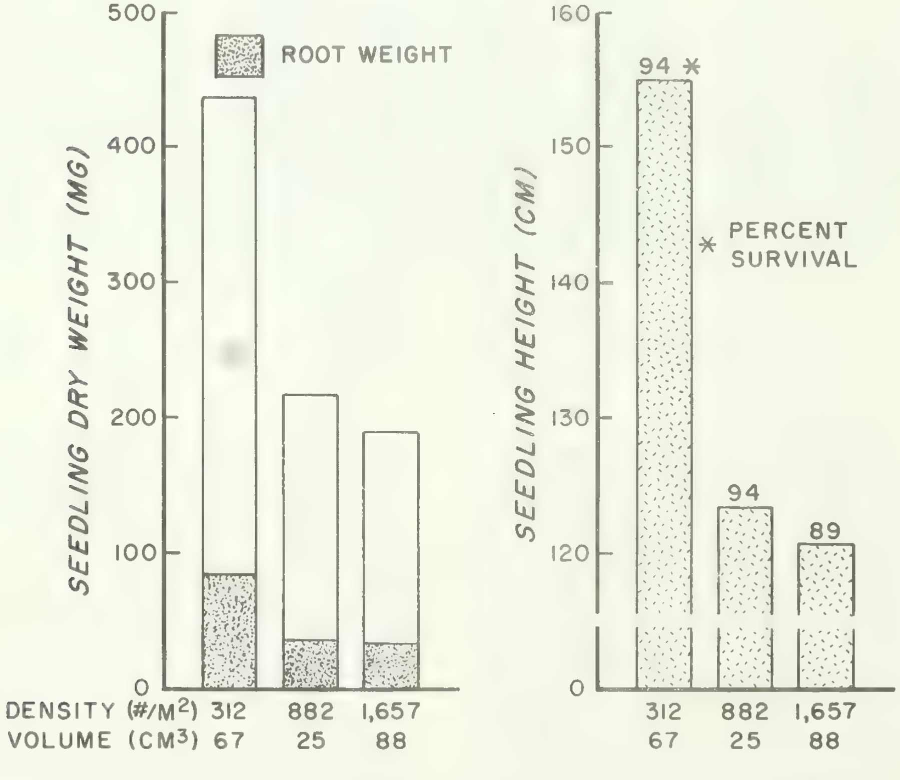


Figure 5-5.—*Effects of container parameters on development and performance of loblolly pine seedlings; height and survival measured after 3 years in the field.*

Table 5-2.—*Major container materials evaluated with southern pines*[1]

Container	Volume[2]		Density[2]		Description
	cm^3	*(in^3)*	*#/m^2*	*(#/ft^2)*	
Tubes:					
Kraft paper	94	(5.7)	1,076	(100)	Square tube, 2.5 × 15 cm (1 × 6 in)
Plastic bullet	30	(1.8)	1,345	(125)	High impact polystyrene, 2 × 11.4 cm (.75 × 4.5 in)
Japanese Paperpot 315	90	(5.4)	1,657	(154)	Special paper, 3 × 15 cm (1.2 × 6 in)
Japanese Paperpot 408	70	(4.3)	1,000	(93)	Special paper, 4 × 8 cm (1.6 × 3.2 in)
Conwed	77	(4.7)	1,162	(108)	Plastic mesh, 3 × 15 cm (1.2 × 6 in)
Biodegradable	64	(3.9)	1,807	(168)	Polycaprolactone, 2.5 × 12.5 cm (1 × 5 in)
Plugs:					
Styroblock 2	40	(2.5)	1,064	(98)	Polystyrene foam, 2.5 × 11.4 cm (1 × 4.5 in)
Styroblock 4	65	(4.0)	807	(75)	Polystyrene foam, 3 × 12.5 cm (1.2 × 5 in)
Styroblock 8	130	(8.0)	441	(41)	Polystyrene foam, 4 × 15 cm (1.5 × 6 in)
Rootrainers:					
Ferdinand	40	(2.5)	1,280	(119)	Polystyrene cellulose acetate, 2 × 10 cm (.75 × 4 in)
Fives	62	(3.8)	882	(82)	Polystyrene cellulose acetate, 2.5 × 10 cm (1 × 4 in)
Hillsons	165	(10.5)	398	(37)	Polystyrene cellulose acetate, 3.8 × 12.5 cm (1.5 × 5 in)
RL Single Cell:					
Pine cell	65	(4.0)	1,076	(100)	Polyethylene, high impact, 2.5 × 16 cm (1 × 6.3 in)
Super cell	164	(10.0)	500	(46)	Polyethylene, 3.8 × 20 cm (1.5 × 8 in)
Stubby cell	100	(6.1)	500	(40)	Polyethylene, 3.8 × 12.5 cm (1.5 × 5 in)
Todd Tray:					
100A	25	(1.5)	882	(82)	Polystyrene foam, 2.5 × 7.5 cm (1 × 3 in)
200	75	(4.6)	312	(29)	Polystyrene foam, 5 × 7 cm (2 × 3 in)
150-5	75	(4.6)	550	(50)	Polystyrene foam, 3.8 × 12.5 cm (1.5 × 5 in)
Tree Planter (ITW)	107	(6.5)	1,076	(100)	Molded polystyrene, 2 × 15 cm (1 × 6 in)
Blocks:					
Gro-block	20	(1.2)	1,861	(173)	Modified cellulose fiber, 1.9 × 9 cm (.75 × 3.5 in)
Polyloam	45	(2.8)	2,485	(231)	Nutrient enriched polyurethane foam, 2 × 10 cm (.75 × 4.0 in)
Kys-Peat-Stick	138	(8.4)	1,033	(96)	Organic-inorganic mixture, 3 × 15 cm (1.2 × 6.0 in)
Kys-Tree-Start	65	(4.0)	1,323	(123)	Organic-inorganic mixture

[1] Other containers and container sizes have been evaluated, but these are the ones where most data are available.

[2] The volumes and densities shown are approximate and may vary according to the level of filling and according to the type of tray in which the containers are supported.

ings (table 5-3). Stem caliper of longleaf pine increased 66 percent when grown in Styroblock-8 instead of Styroblock-4 containers. The comparative increase for loblolly stem calipers was only 19 percent.

5.4 Containers and Root Form

When planting any tree, you risk having a root system that is deformed, at least to the extent that it will not have the same root configuration as trees grown from seed in place. Many investigations have focused on root deformation (Hulten 1982, Van Eerden and Kinghorn 1978). Yet, there is still no clear determination of effects of root malformation on seedling performance.

Our results with southern pines indicate that the severe constraint of many of the tube-type containers adversely affects seedling growth. For example, plastic bullets can limit root egress to the extent that growth is stunted (fig. 5-7). Other containers can result in root strangulation (fig. 5-8) or root spiraling (fig. 5-9). If, however, these obvious extremes of deformity are avoided, the configuration imposed by the container may not be harmful. Block-type containers seem to impart less of an "oriented" root system than bare-root planting. Root egress from blocks such as Kys-Tree-Starts occurs from the entire surface of the block in a natural manner (fig. 5-4).

The effect of plug-type containers on root configuration can vary greatly. Round cavities as in the styroblock container can result in root spiraling if vertical ribs are not incorporated to force root growth downward; ribs effectively reduce root spiraling.

Studies have also shown that the amount of root malformation varies with species and soil type. Long-

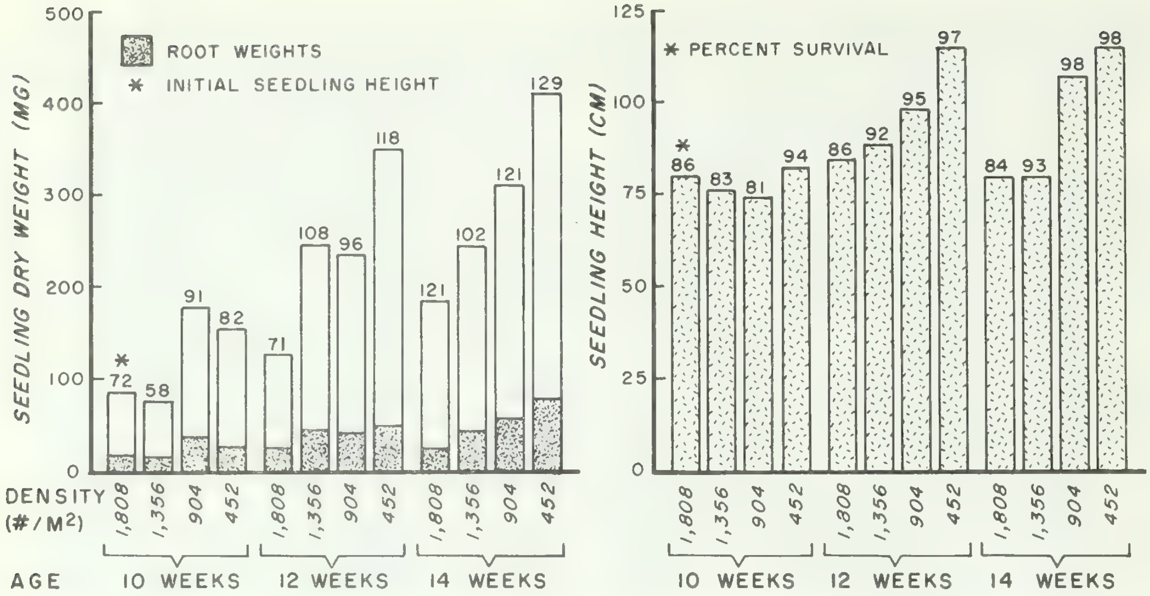


Figure 5-6.—*Effects of seedling density and age on development and field performance of loblolly pine seedlings; measurement taken at 2-1/2 years.*

Table 5-3.—*Development of loblolly and longleaf pine seedlings as related to container size and seedling density*

Species	Container	Seedling development[1] Stem caliper	 Top weight	 Root weight
		--- *mm* ---	---------- *mg*[2] ----------	
Loblolly	Styroblock-4	2.6	840	162
	Styroblock-8	3.1 (19%)[3]	1,482 (76%)	237 (46%)
Longleaf	Styroblock-4	2.9	975	135
	Styroblock-8	4.8 (66%)	2,185 (124%)	364 (169%)

[1] Loblolly and longleaf seedlings were 16 and 20 weeks old, respectively, when these measurements were made.

[2] Dry weights.

[3] Values in parentheses are proportional increases in seedling development due to the larger container.

leaf pine is more susceptible to root spiraling than loblolly or slash, probably because the lack of early stem growth results in more rapid root elongation. With punched planting holes, heavy soils can increase the amount of root malformation by limiting rapid root egress through the planting hole wall (Barnett 1978a) (see section 12.5). Root spiraling can occur within the planting hole when holes are punched in heavy clay soils. However, with reasonable precautions in selection of containers and planting techniques, root configuration should not adversely affect seedling growth and development. The development of adverse root forms increases rapidly with the length of time seedlings are grown in containers With 12- to 15-week growing cycles and removal o the seedlings from the container, there should be n problem if you are using properly designed containers.

5.5 Containers for Specific Applications

Certain uses of containerized seedlings mak specific types and sizes of containers necessary. A fe of these more specific applications are discussed below. Planting of container-grown seedlings is discussed in greater detail in section 12.5.

5.5.1 *Hand-Planting Operations*—Seedlings grown n plug-type containers are generally best adapted to hand planting. The planting rate using punch-type dibbles usually exceeds that of bare-root stock because of the tapered configuration of the root mass (Vyse 1971). The planting hole does not have to be closed with the dibble as in bare-root planting if the punch is shaped like the container plug. Several planting tools for plugs are also designed so that the seedlings are dropped through the barrel of the tool and the planter does not have to bend over (fig. 5-10). Both tubes and blocks are more difficult to plant by hand. Tube containers shaped like bullets are the exception, but these seriously constrict the root system and inhibit growth (Arnott 1973).

5.5.2 *Mechanized Planting Operations*—Although extractable plugs seem well suited to hand planting, they are not well adapted to an automated tree planter (Edwards 1974). Tube and block-type containers lend themselves more easily to a mechanized planting system because of their rigidity and durability. In many areas, especially in the Southeastern States, an automated planter will work effectively and avoid labor intensive and costly hand planting. Edwards (1982) discusses the development of semiautomatic and automatic planters and the problems involved in their development.

5.5.3 *Forest Genetics Programs*—One of the advantages of container planting listed earlier was to increase efficiency of genetically improved seeds. A more specific application in this regard is to produce seedlings for progeny tests. Use of containers allows complete utilization of limited quantities of seeds and also results in very uniform seedlings. Because of the full utilization of seeds, it may be possible to begin progeny evaluations several years before they could be started if seedlings were grown in forest nurseries. Even if sufficient seeds are available, container-grown seedlings can be in the field one growing season before bare-root plants, if seed extraction is done promptly and the seedlings are grown over the winter months (van Buijtenen and Lowe 1982).

It may be desirable to grow seedlings for progeny tests in containers larger than normally used for operational production. This would allow development of high-quality seedlings in a relatively short time. RL Single-Cell containers are ideal for this use, because individual tree randomization can be accomplished in

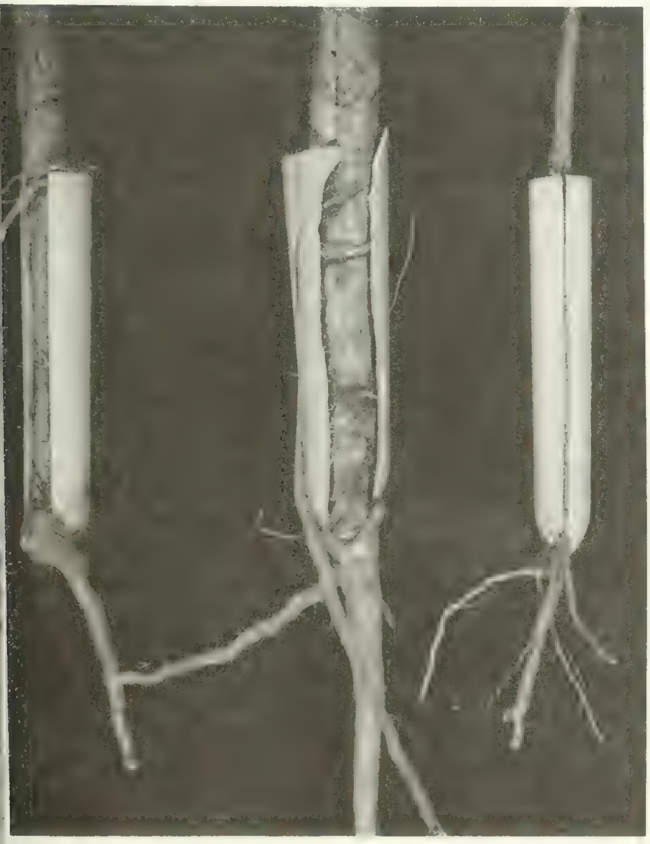


Figure 5-7.—*Loblolly pine seedlings grown in and outplanted with plastic bullets and excavated after 3 years. Various stages of root constraint are shown.*

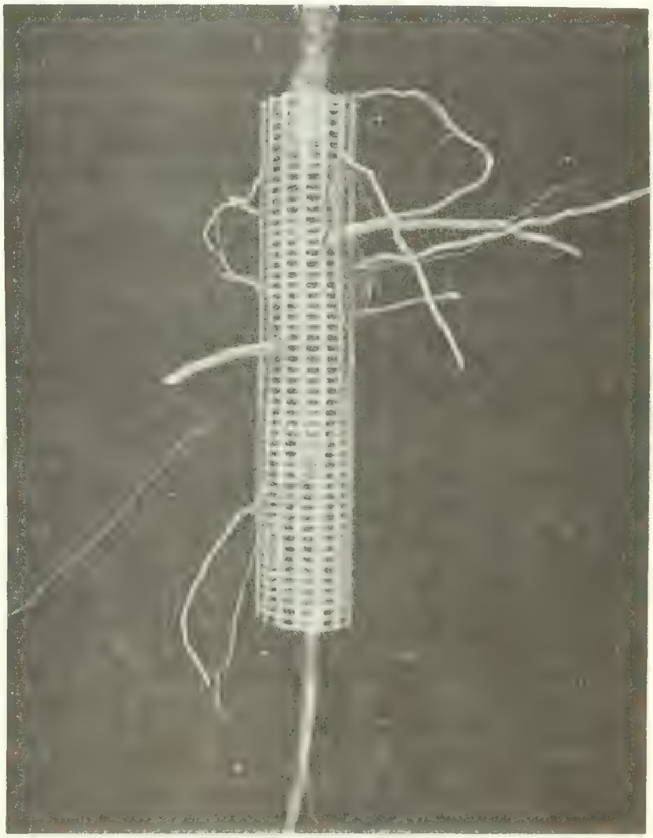


Figure 5-8.—*Conwed mesh-type container showing configuration of loblolly pine roots about 3 years after outplanting.*

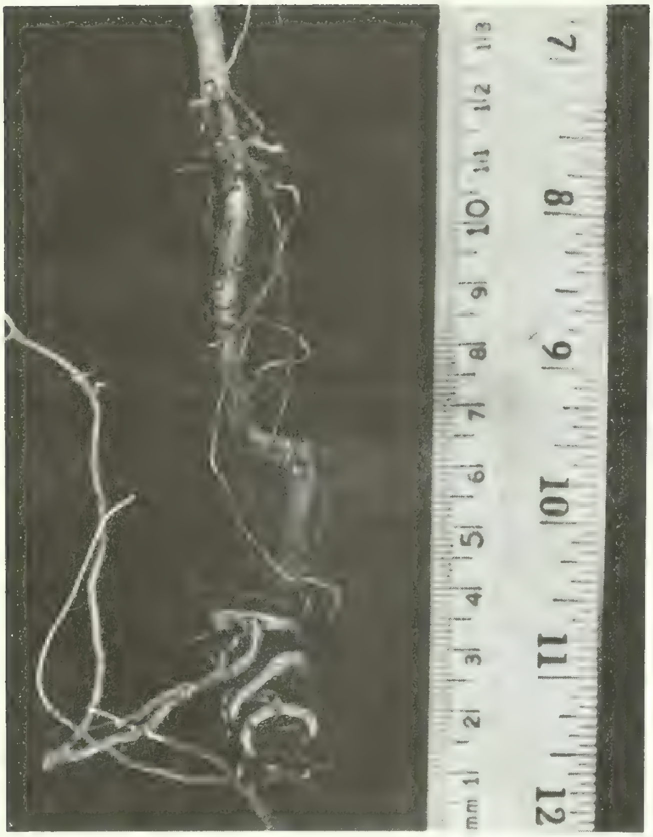


Figure 5-9.—*Root system of loblolly pine seedling showing deformation at the bottom of the styroplug, below the extent of the vertical ribs.*

the greenhouse, blank cavities can be removed, and seedlings per unit area and other factors affecting seedling quality can be easily controlled.

5.5.4 *Problem Species and Sites*—Nursery-grown seedlings of some species are difficult to plant successfully. Longleaf pine and Fraser fir (*Abies fraseri* (Pursh) Poir.) are two species that are difficult to grow in bare-root nurseries. Longleaf pine, because of its dormant epicotyl or "grass stage" characteristic, produces rapid root development. During lifting of nursery-grown seedlings a large proportion of this root system is lost and the resulting field survival is usually lower than for other southern pine species. Fraser fir develops slowly in seedbeds, requiring 3 years to reach transplantable size in bare-root nurseries. Both species seem well adapted to production in containers. The root systems remain intact and cultural conditions hasten development, so that plantable seedlings are obtained in a relatively short period.

Certain sites are typically difficult to plant with success. Examples of problem sites are (1) dry, sandy soils, (2) mine spoil banks, (3) highly erosive soils, and (4) low, poorly drained soils. Many of the dry, sandy soils throughout the southern United States were originally longleaf pine sites, but difficulties in planting this and other species have slowed regeneration of these areas. Amidon and others (1982) showed that container-grown longleaf seedlings did much better than bare-root seedlings on these harsh sites (table 5-4). Mine spoils present very difficult sites to regenerate in parts of the South, and although the total acreage is relatively small, Davidson and Sowa (1974) demonstrated that containerized seedlings may do well on these areas, particularly when seedlings are inoculated with mycorrhizae adapted to these soils (Marx and Bryan 1975). Dickerson (1973) also reported that container-grown seedlings gave promising results on severely eroded forest sites caused by poor agricultural practices. Early summer planting of containerized seedlings is a practical means of regenerating many of the low, poorly drained soils where roads are not accessible in the winter months.

6. GROWING MEDIUM

6.1 Selection of the Medium

Numerous natural and artificial soils have been used alone and in combination as a plant growing medium. Good topsoil is increasingly difficult to find, and its nutrient content, drainage characteristics and disease organism or weed seed content are difficult to determine. Unless topsoil is sterilized, poor crop growth often results from its use (Boodley and Sheldrake 1963). Artificial mixes are readily available, easy to handle, and produce uniform plant growth from one year to another.

A number of workers have evaluated combinations of artificial soil mixes (Edgren 1973, Phipps 1974, Hellum 1975, Matthews 1971; Goodwin 1976, Pawuk 1981). Almost without exception, the combination resulting in best seedling performance involved sphagnum peat moss and vermiculite. Sphagnum moss provides good water holding capacity, a low pH (see section 9.5), good buffering capacity, and a high cation exchange capacity. Vermiculite provides pore space thus ensuring good aeration for root growth. The ratio of peat to vermiculite most often used is 1:1 or sometimes 2:1.

Domestic peat moss is generally unsatisfactory because of the large quantities of nutrients or other materials in unknown amounts and because it is usually too decomposed to provide the necessary structural and water drainage capacities (Phipps 1974). Canadian peat moss is recommended, but because of the transportation costs to the southern United States, alternative materials have been evaluated.

Because it is readily available and relatively inexpensive, pine bark has been suggested as a medium for growing plants (Scarborough 1979). Results to date have indicated that bark has physical properties making it a possible alternative to peat moss

igure 5-10.—*Using tools for hand planting containerized seedlings can increase the planting rate.*

Pokorny and Perkins 1967, Brown and Pokorny 975). Other advantages of bark are excellent mycorhizal development (Ruehle and Marx 1977) and posible inhibition of disease organisms (Pawuk 1981). Media incorporating pine bark or pine cone chips reulted in significantly less mortality when infested with *Fusarium* and *Phythium* than commercial or loally blended peat and vermiculite mixes (table 6-1). Seedling mortality was related to drainage and pH of he media. Seedling losses were greatest in commerial media with pHs above 6.0 and increased as waterholding capacity of the medium increased. However, pine bark also has certain disadvantages. A nitrogen deficiency problem develops in bark-amended media, which requires special attention. This has caused some researchers to recommend against the use of bark as a medium ingredient (Mitchell and Kay 1973). The use of milled bark in plug-type containers results in difficult extraction and in poor binding by the root system. Another characteristic of bark is poor water retention capacity (Johnson 1968). Although rapid drainage reduced disease problems, it resulted in the need for more frequent watering during the greenhouse growing phase and in rapid depletion of moisture from the medium when outplanted in the field.

Comparisons of composted and milled fresh bark indicate that the aged bark results in fewer growing problems (Mason and Van Arsdel 1978, Gartner 1979). If properly handled, hardwood bark can also be used satisfactorily; however, the pH increases from about 5.2 for fresh bark to 7.5 to 8.0 as it ages (Gartner 1979). Iron sulphate and elemental sulfur must be added to compensate for this decrease in activity.

Until more information is available, bark should be used only as a partial replacement for peat in the growing medium. Our current data indicate that although there is no universal medium, the peat-vermiculite blend is still the most satisfactory (tables 6-1, 6-2).

6.1.1 *Commercial Mixes*—A number of commercial potting mixes are available for container growing. Almost all of these are based on the Cornell mixes, which consist of various ratios of peat moss, vermiculite, and perlite (Boodley and Sheldrake 1963). To these blends are added nutrients and enough dolomitic limestone to buffer the media to a pH of about 6.0. These blends have been developed for horticultural and vegetable use and are unsuitable for conifers unless special precautions are taken to reduce the pH to levels more nearly optimum for conifers. A few producers will custom blend and reduce the amount of limestone so the pH is more satisfactory for growing coniferous species. The advantage of peat-vermiculite mixes with low levels of limestone (or none) is evident when compared to commercially blended peat-vermiculite mixes (Jiffy Mix®) produced for horticultural uses (tables 6-1, 6-2). The nutrients in Cornell-type mixes are sufficient for the first several weeks, but then supplemental fertilizers should be added.

6.1.2 *Other Blends*—Any number of mix combinations are possible if the grower has access to blending equipment. Small quantities suitable for uses such as progeny testing can be mixed by hand. However, when quantities needed exceed a few cubic meters, other arrangements for mixing must be made. Commercial concrete mixers may be rented for occasional

Table 5-4.—*Longleaf pine seedling survival and root-collar diameters on two dry sites following extremely harsh drought conditions in the summer of 1980[1]. Adapted from Amidon and others (1982)*

Container	Survival		Root-collar diameter	
	Louisiana	Texas	Louisiana	Texas
	------- *percent* ------		------- *mm* --------	
Late summer planting (August 1979)[2]				
Kys-Tree-Start	70	38 c	10 b	10 c
Styroblock-4	70	66 b	10 b	13 b
Styroblock-8	88	77 a	13 a	15 a
Site average	76 a	60 b	10 b	13 a
Spring planting (March 1980)				
Bare-root seedlings	7	43 b	10 a	10 a
Todd-150-5	33	60 a	8 a	8 a
Styroblock-4	37	70 a	10 a	8 a
Styroblock-8	23	66 a	10 a	10 a
Site average	31 b	65 a	10 a	10 a

[1] Measurements taken in January 1981.

[2] Container treatment means within columns and site averages within rows followed by the same letter are not significantly different at the 0.05 level for each of the two plantings.

Table 6-1.—*Growth and disease development of 12-week-old longleaf pine seedlings grown in peat, pine cone, and pine bark media (Pawuk 1981)*

Medium[1]	Final pH	Dry Weight	Seedling loss due to[2]	
			Fusarium	*Pythium*
		mg	----- *percent loss* -----	
Peat				
PV-50	5.1 e[3]	798 a	00 a[3]	40 cd
Commercial (PV-50)	6.2 b	755 a	08 bc	94 f
Pine Cone				
CV-50	6.1 bc	636 b	00 a	46 d
CV-70	6.1 bc	619 bc	06 abc	40 cd
C-100	5.9 c	562 cd	00 a	36 bcd
CS-70	5.9 c	628 b	02 ab	26 abcd
Pine Bark				
BV-50	5.2 d	510 de	00 a	24 abc
BV-70	4.9 f	452 ef	00 a	16 ab
B-100	4.6 g	460 ef	02 ab	06 a
BS-70	5.1 e	530 d	00 a	1.6 ab
Jiffy 50-50 (BV-50)	6.4 a	420 f	16 d	68 e
Jiffy 70-30 (BV-70)	6.4 a	410 f	12 cd	88 f

[1] P = peat; V = vermiculite; C = cone chips; B = bark; S = soil: the number following the medium designation indicates the percentage of peat, bark, or cone chips present.

[2] Medium infected with *Fusarium* and *Pythium* at the time of blending.

[3] Means followed by the same letter are not significantly different at the 0.05 level.

Table 6-2.—*Seedling growth of 12-week-old shortleaf pine grown in peat, pine cone, and pine bark media. Adapted from Pawuk (1981)*

Medium[1]	Media final pH	Seedling Weight	Seedling Height
		mg	*cm*
Peat			
PV-50	5.4 c[2]	523 a	10.87 a
Commercial (PV-50)	6.4 a	383 b	9.72 b
Pine Cone			
CV-50	5.9 b	301 c	7.85 c
CV-70	6.0 b	259 de	7.46 cd
C-100	5.8 b	125 ij	6.08 fg
CS-70	5.9 b	270 cd	7.79 c
Pine Bark			
BV-50	5.4 c	216 f	6.18 fg
BV-70	5.0 d	201 fg	6.15 fg
B-100	4.9 d	175 gh	5.63 g
BS-70	5.3 c	224 ef	6.96 de
Jiffy 50-50 (BV-50)	6.4 a	90 j	5.54 g
Jiffy 70-30 (BV-70)	6.5 a	154 hi	6.62 ef

[1] P = peat; V = vermiculite; C = cone chips; B = bark; S = soil: the number following the medium designation indicates the percentage of peat, bark, or cone chips present.

[2] Means followed by the same letter are not significantly different at the 0.05 level.

use, but large operations are generally best served by purchasing their own blending equipment. Ribbon blenders are available in a number of sizes, but a 0.8 m^3 (28 ft^3) blender is adequate for most operations. This type of blender can thoroughly mix the medium with any additional amendments in 10 to 15 minutes. Addition of water during the blending process reduces dust problems and also prevents the media from falling out of the bottom of the containers during filling and handling. Enough water should be added to thoroughly moisten the mix, but not so wet that water can be wrung from a handful.

6.2 Amendments

6.2.1 *Wetting Agents*—Several types of amendments can be added to the medium as it is blended. The addition of a wetting agent is desirable because it increases the uniformity and rate at which moisture spreads through hydrophobic peat. Most commercial peat mixes contain small amounts of such an additive, but growers blending their own medium must add a wetting agent separately. The amount added must be carefully controlled to avoid phytotoxicity to the germinating seed. In some cases, the manufacturer's recommended concentration may be too high. Burridge and Jorgensen (1971) reported that wetting agents reduced the speed of germination and radicle development of several northern conifer species. Edwards (1973) found that low concentrations had negligible effects on germination.

Aqua-Gro®, a 1:1 mixture of polyoxethylene ether and ester used widely in nursery operations in the United States, was evaluated on southern pine seed germination (Barnett 1977). The recommended rate (0.1 percent) reduced germination of longleaf, slash, loblolly, and shortleaf (*Pinus echinata* Mill.) pine seeds. The application rate should be lowered to 0.02 to 0.04 percent, which provides adequate wetting without reducing germination (fig. 6-1). Applications can also be made through the watering system after the medium is blended and containers are filled.

6.2.2 *Fertilizers and Fungicides*—A balanced fertilizer combination is usually blended into commercial potting mixes. Both the University of California (Baker 1957) and Cornell University (Boodley and Sheldrake 1963) have developed potting mixes in which nutrients are incorporated. Modification of these or other nutrients can be included as the mixes are blended. There may be merit in incorporating slow release fertilizers such as Osmocote® into the media. Specific nutrient formulations are discussed in section 9.6.

Fungicides to control root rot and damping-off diseases may also be incorporated at the time of blending (see section 9.2.1) (Pawuk and Barnett 1974, Walters 1975). Such applications may be more effective than drenches done after disease symptoms appear.

6.2.3 *Hydrophilic Polymers*—The addition of hydrophilic polymers to potting media greatly increases the water-holding capacity and availability of water (Jensen and others 1971). The incorporation of these polymers into the media increases the ability of plants to withstand drought conditions and lessens the amount of watering needed to produce plants.

Two such amendments, Viterra I® and Viterra II®, have been evaluated with forest tree species. Tests of effects on initial seedling development indicate no significant improvement in seedling size. However, trends are indicative of some response (table 6-3). Field results to date are inconclusive because of the lack of moisture stress. Other materials have similar properties, including synthetic- and starch-based superabsorbents such as Tera-Sorb®. The use of such amendments is generally unnecessary in well run container nurseries.

7. SEED

7.1 Seed Lot Selection

Many species have sufficient racial variation to necessitate collection from specific seed collection zones for planting in certain regions. For example, loblolly pine from some geographic areas grows faster and has more disease resistance when planted on other areas

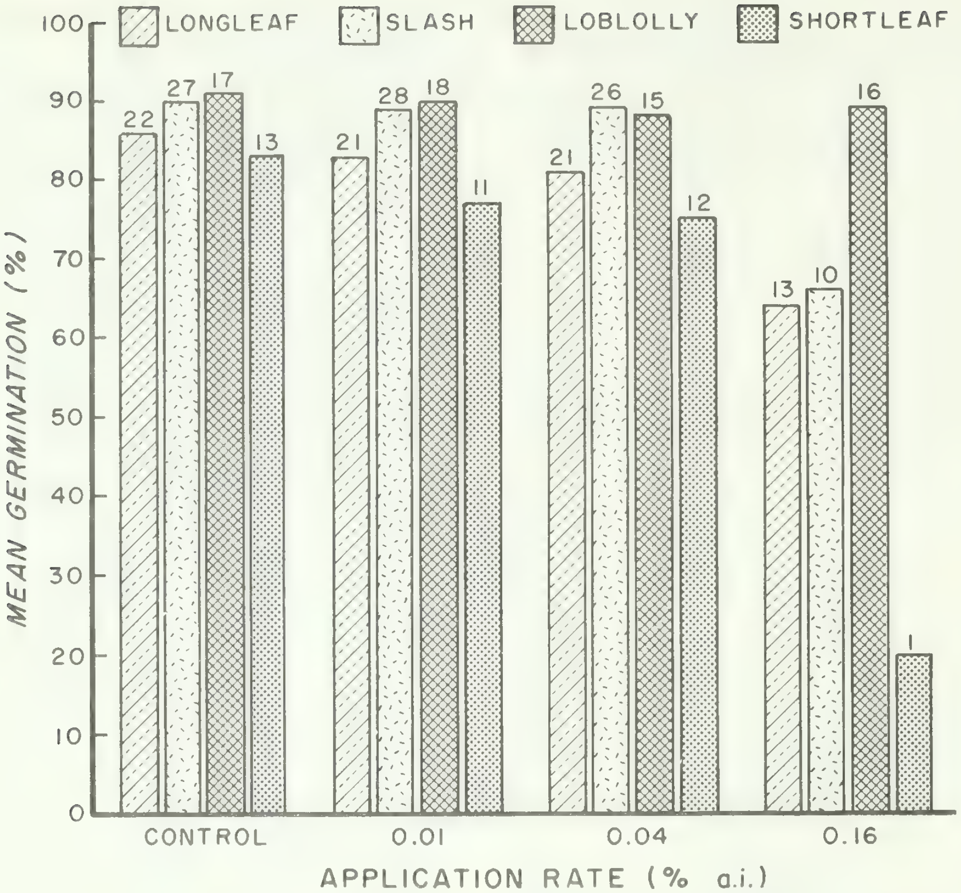


Figure 6-1.—*Germination percentages and germination values of longleaf, slash, loblolly, and shortleaf pine seeds after treatment of the growing medium with a wetting agent. Numbers above bars are mean germination values (peak germination X daily germination at 30 days (from Barnett 1977).*

Table 6-3.—*Seedling development of 12-week-old longleaf pine grown with hydrophilic polymer additives*[1]

Treatments	Root collar diameter	Dry weight of tops	Dry weight of roots
	mm	*mg*	*mg*
Control	1.98	552	85
Viterra I	2.02	583	71
Viterra II	2.38	702	93

[1] Grown in Union Carbide biodegradable tubes filled with peat-vermiculite media.

in the South (Wells and Wakeley 1966). Similar seed source recommendations have been developed for longleaf (Wells and Wakeley 1970a), shortleaf (Wells and Wakeley 1970b), and slash pine (Snyder and others 1967).

Once seeds from an appropriate geographic source have been selected, high seed quality becomes the paramount concern, because maximum utilization of containers is necessary to make the system economically justifiable.

7.2 Collecting and Processing Seed

The high quality seed necessary for use in container-planting facilities results from operations where cone and seed collecting and processing methods are carefully controlled (Barnett 1976a).

Cone maturity at the time of collection can have a major impact on the seed quality of slash and longleaf pine. Loblolly seeds usually have high viability, even when collections begin early. Detailed information on the effects of cone maturity and storage on seed yield and viability are available for these species (Barnett 1976b, McLemore 1961, 1975b).

Seeds are usually extracted from southern pine cones in forced-draft kilns. Temperature and duration of kilning are critical for southern pines, particularly longleaf. Temperatures over 45 °C (115 °F) markedly reduce germination (Rietz 1941). Alternative methods of extracting and drying southern pine seeds are under evaluation and may result in increased seed quality (Barnett 1979a).

After seeds are extracted, they must be dewinged, cleaned, and dried. The wings on seeds of all southern pines, except longleaf, are completely removed by brushing and tumbling in mechanical dewingers where the wings are mechanically removed. The structure of longleaf makes dewinging difficult, so dewingers must be carefully regulated to prevent injury to these thin-coated seeds. Storage of longleaf pine seeds will be adversely affected if wing removal damages the seedcoat (Barnett 1969a, Belcher and King 1968). The dewinging process for the other southern pine species is hastened and improved by moistening dry seeds, but this excess moisture should be removed prior to storage.

Complete removal of unsound seed should be specified when seed lots are purchased. When seed lots are small, it is often convenient to do your own processing. Small laboratory cleaners or aspirators are available that are quite efficient (Bonner 1977). Separation by flotation in water or organic solvents also can be used. When the appropriate liquid is used, sound seed sinks, while unsound seed floats and can easily be skimmed off. For flotation of southern pine seeds, use water for loblolly pine; 95 percent ethyl alcohol for shortleaf, sand (*Pinus clausa* (Chapm. ex Engelm.) Vasey ex Sarg.), and spruce (*P. glabra* Walt.) pines; a water-ethyl alcohol mixture (1:1) for slash pine; and *n*-pentane for longleaf pine (Barnett and McLemore 1970). Flotation in ethyl alcohol should not be done until just prior to use, because viability rapidly declines during storage unless the alcohol is thoroughly removed by drying (Barnett 1971b).

7.3 Seed Storage

Careful control of seed moisture content and storage temperature is essential to maintain viability (Barnett and McLemore 1970, Jones 1966). General recommendations for long-term storage are to dry seeds to 10-percent or less moisture content and hold at subfreezing temperatures (fig. 7-1). Seeds that are damaged or are known to have low vigor can be preserved by lowering storage temperatures to about −18 °C (0 °F) (Kamra 1967), if moisture contents are as low as 8 to 10 percent. Storage at temperatures near −18 °C (0 °F) can reduce viability if moisture levels are 20 percent or more (Barnett 1974c).

Seed moisture content can also affect the amount of undesirable secondary dormancy that develops during storage (fig. 7-2). Seed dormancy is related to germination values (Czabator 1962), which reflect speed as well as completeness of germination, and low values reflect more dormant seeds. Loblolly seeds stored for 1 to 5 years at moisture levels below 10 percent are less dormant than those held at levels between 10 and 18 percent (McLemore and Barnett 1968).

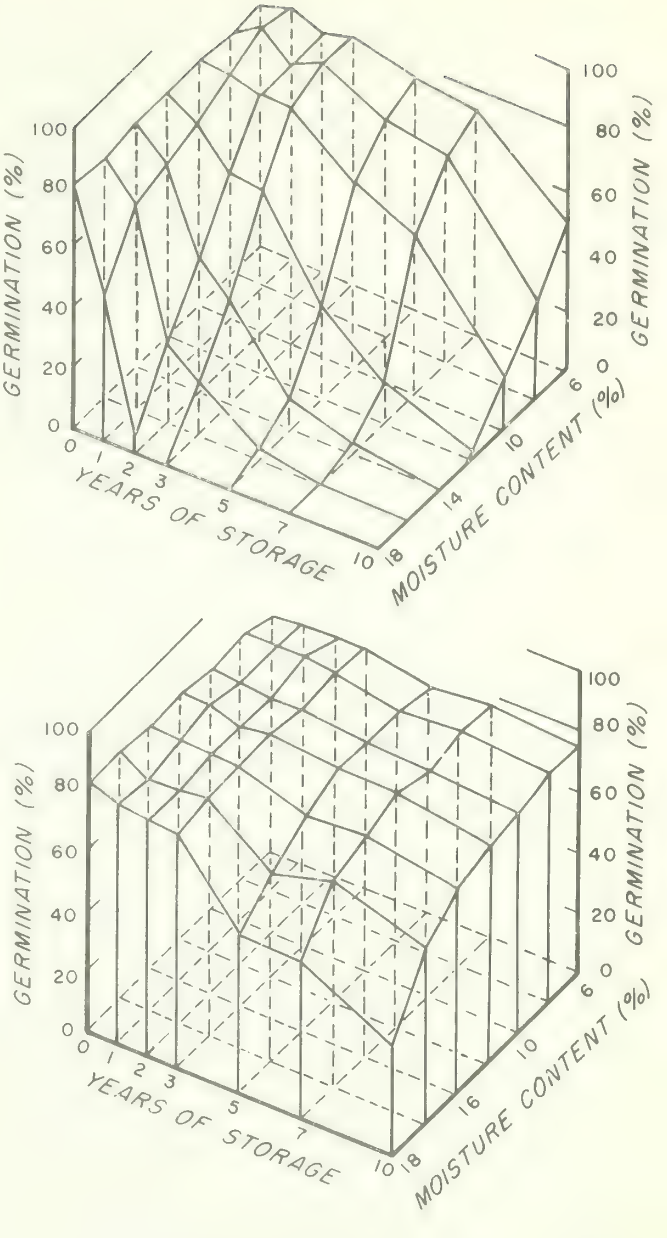


Figure 7-1.—*Germination of longleaf pine seeds as influenced by moisture content and years of storage at 2 °C (top) and −18 °C (bottom).*

7.4 Seed Sizing

The reported effects of seed size on germination and early seedling growth are conflicting. In general, large seeds have been found to germinate faster and more completely than small seeds and to produce seedlings whose initial growth is greater (Shoulders 1961, Fowells 1953, Righter 1945). This growth advantage usually has not been retained after the first few years. However, with the limited information available, many growers of containerized seedlings

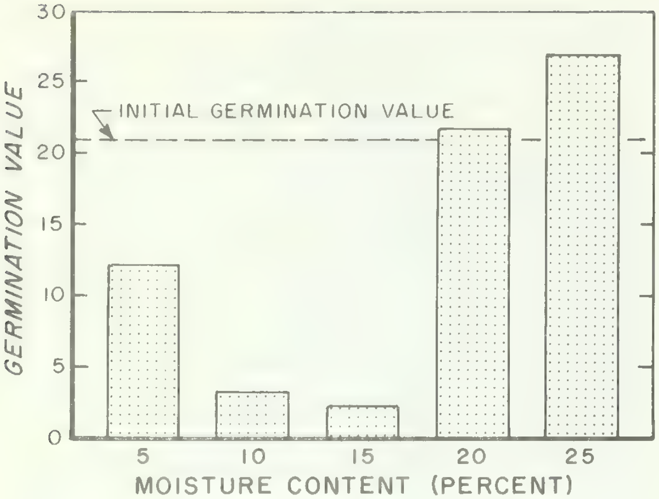


Figure 7-2.—*Germination values of unstratified loblolly pine seed stored for 1 year at moisture contents of 5 to 25 percent (from McLemore and Barnett 1968).*

still recommend seed sizing. The objective is to produce uniform sized crops of seedlings (Owston 1972). Medium to medium-large seeds have been reported to be best (Ghosh and others 1976). Larsen (1963) reported that although seed size can influence seedling size when seedlings are grown under uniform conditions such as greenhouses, the importance of size is minor when compared to the effect of germination date. Uniformity of germination may be, then, the most important consideration in sizing.

Sizing of genetically improved orchard seeds seems to have little effect on seedling performance (table 7-1). Grouping for production of uniform seedlings is probably the only reason to size these seeds (Barnett and Dunlap 1982). Certainly all sizes should be used, or certain clones will be segregated from a mixed seed lot (Silen and Osterhaus 1979). The large seeds listed in table 7-1 were primarily from two clones. Seed size tends to be consistently uniform from year to year within clones (McLemore 1975a), so sizing could easily segregate orchard seed lots.

Seed sizing was examined as a possible method for manipulating the size of containerized seedlings produced from a single half-sib family of loblolly pine (Dunlap and Barnett 1983). Under laboratory conditions of minimal environmental stress, germinant size after 28 days of growth was strongly correlated with seed size. The faster germinating seeds in each size class produced larger germinants after 28 days of incubation (fig. 7-3). The rate of germination was related to seed size. All seeds reached a maximum rate by the sixth day, but smaller seeds were slower to initiate germination (fig. 7-4). In a similar experiment conducted under greenhouse conditions, large seeds produced the largest seedlings.

Seedling size differences in both experiments appeared to result from differences in the rate of germination, which seems to be characteristic of each size class. This supports the findings of Venator (1973), indicating that faster growing Caribbean pine (*P. caribaea* var. *hondurensis* Barrett & Golfari) seedlings tend to develop from early germinating seeds. Consequently, seedling size and possibly uniformity of growth were primarily a function of germination patterns, which were partially determined by seed size. However, germination patterns also can be manipulated by pregermination treatments. For example, long stratification periods tend to eliminate differences in rate of germination.

7.5 Seed Dormancy

The seeds of nearly all 10 species of pines indigenous to the southern United States exhibit some dormancy. There has been little agreement on the cause of this dormancy. It has been attributed to impermeability of the seedcoats to oxygen (Stone 1957, Kozlowski and Gentile 1959, Asakawa 1964), germination inhibitors (Barnett 1970), or to some condition in the embryo (Kramer and Kozlowski 1960). However, recent studies have established that inherent dormancy in the southern pines is most likely a result of mechanical seedcoat constraint (Barnett 1972,

Table 7-1.—*Effect of size of genetically improved loblolly pine seeds on initial seed and seedling performance and field survival and growth (from Barnett and Dunlap 1982)*

Seed size class	Seeds per pound	Proportion of lot per class	Germination		Seedling characteristics				Field performance[1]	
			Unst.	Strat.	Ht.	Diam.	Top Wt.	Root Wt.	Survival	Height
	number	------- *percent* -------			--- *mm* ---		------ *mg* ------		*percent*	*cm*
Unsorted	17,059	....	87 b[2]	89 b	125 a	1.5 a	225 a	52 a	85 a	128 ab
Small	20,100	19.9	86 b	87 ab	146 b	1.6 ab	297 ab	59 a	84 a	131 b
Medium	17,518	36.1	89 b	90 b	130 a	1.6 ab	260 a	44 a	89 a	128 ab
Medium-large	15,406	41.8	88 b	83 a	154 b	1.7 b	328 b	60 a	84 a	101 a
Large	13,089	2.1	79 a	83 a	150 b	1.7 b	316 b	59 a	81 a	122 ab

[1] At 30 months.

[2] Values in columns followed by the same letter are not significantly different at the 0.05 level.

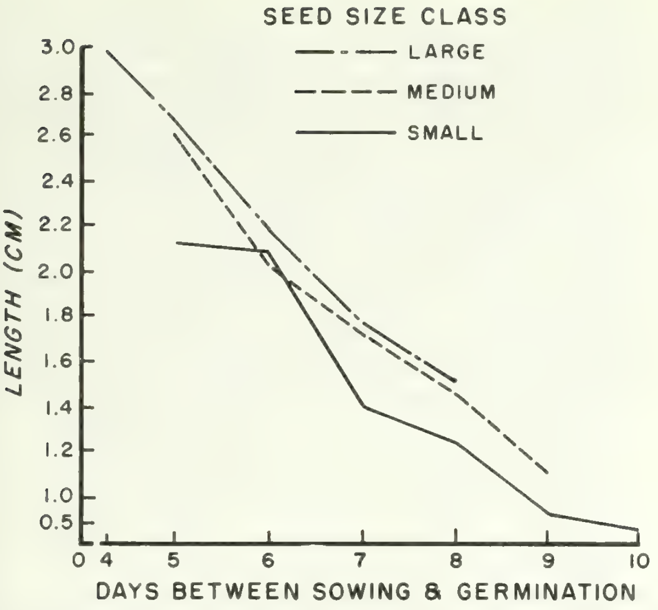


Figure 7-3.—*Mean hypocotyl length of loblolly pine germinants 28 days after germination (from Dunlap and Barnett 1983).*

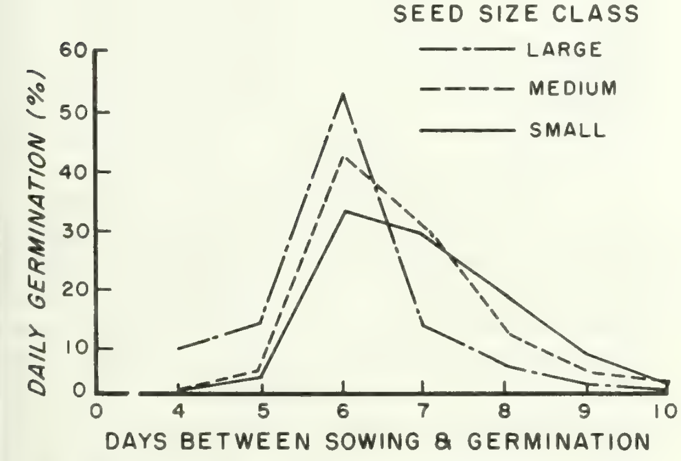


Figure 7-4.—*Mean daily germination of loblolly pine seed from the large, medium, and small classes incubated under standard laboratory conditions (from Dunlap and Barnett 1983).*

1976c). This innate dormancy can be increased by unfavorable conditions during processing and storage (McLemore and Barnett 1966, 1968). For example, dormancy of loblolly pine seeds is markedly increased when stored at moisture contents of 10 to 18 percent (fig. 7-2). Moisture levels below 10 percent during storage minimizes this induced dormancy. Storage at a moisture content of 20 percent or more has a stimulating, prechilling effect.

Seeds of several of the southern pines are routinely treated before use to obtain complete and uniform germination. Pregermination treatments increase the growth potential of the embryo, allowing seeds to germinate more promptly (see section 7.6).

7.6 Presowing Treatments to Speed Germination

7.6.1 *Stratification*—Presowing treatments to speed pine germination are discussed in detail by Bonner and others (1974) in *Seeds of Woody Plants in the United States*. Although the term stratification refers to the layering of seeds in a good moisture-retaining medium such as peat moss, stratification is now used to describe any cold, moist seed treatment. Southern pine seeds are typically prechilled in polyethylene bags. After an 8- to 24-hour period of moisture imbibition, fully imbibed seeds are placed in bags and held at temperatures of 1 to 5 °C (34–41 °F). Temperatures below freezing may injure imbibed seeds (Barnett and Hall 1977) while those above 5 °C (41 °F) may cause germination. The length of stratification depends on the species and time in storage. General recommendations for length of treatment are given in table 7-2. However, if unusually low or high temperatures are anticipated during the germination period, or if greater uniformity of germination is desired, then the period of stratification should be lengthened. Periods of stratification of 45 to 90 days not only hasten germination over that of the 30-day treatment but also result in better germination under adverse conditions (McLemore 1969, Barnett 1979b).

7.6.2 *Aerated Water Soaks*—Cold water soaks have been used to promote germination of some coniferous species (Bonner and others 1974), but soaks longer than a few days tend to reduce germination of southern pines (Barnett and McLemore 1967). However, soaking loblolly, slash, and shortleaf pine seeds in

Table 7-2.—*Recommended cold stratification periods for southern pine seed (adapted from Krugman and Jenkinson 1974)*

Pine species	Recommended length of stratification[1]	
	Fresh seed	Stored seed
	days	
Loblolly	30–60	30–60
Longleaf	0	0
Pitch	0	0
Pond	0	0–30
Sand		
var. Choctowhatchee	0–15	0–21
var. Ocala	0	0
Shortleaf	0–15	15–60
Slash	0	0–30
var. So. Florida	30	30
Spruce	30	30
Table Mountain	0	0
Virginia	0–30	30

[1] Use longer period of stratification if adverse environmental conditions are expected when seeds are sown.

continuously aerated water at 5 °C (41 °F) speeded germination in the laboratory as much as stratification in polyethylene bags (Barnett 1971a). Soaking at 10 °C (60 °F) stimulated germination as much as colder soaks and did so in less time. Although dormant loblolly seeds can be soaked at low temperatures for nearly 5 months without harm, periods of up to 60 days are usually sufficient. With less dormant seeds and higher soaking temperatures, periods as short as 2 or 3 weeks may be necessary to prevent germination in water and induction of secondary dormancy. The water should be aerated continuously to keep the oxygen content near saturation.

An outgrowth of aerated water soaks has been the fluid drilling, or germinant sowing, technique (Currah and others 1974). In fluid drilling, seeds are allowed to begin to germinate to a radicle length of 1 to 2 mm in aerated water. These germinants are then placed in a solution of appropriate specific gravity to separate the germinants from ungerminated seeds (Taylor and others 1977). The germinants are then mixed in a viscous gell to protect the seeds and to provide a means of drilling (sowing) these seeds onto the nursery beds. Research is underway to evaluate the potential of this technique for southern pine seeds. Although firm recommendations have not been developed, if certain criteria are followed, about 85 percent germination of loblolly pine seeds can be obtained in 4 to 5 days (Barnett 1985). This is accomplished without the separation of germinated and ungerminated seeds, which is now impractical for loblolly seeds. Guidelines to use for pregerminating loblolly seeds are:

1. Stratify seeds for 60 days prior to aerated-water germination.
2. Germinate at a temperature of 24 °C (75 °F).
3. Provide about 1600 lux (150 foot-candles) of light with a 16-hour photoperiod during germination.
4. Use high quality seed lots (>90 percent germination) to avoid separation of ungerminated seeds.

Other pine species will require less stratification because they are less dormant than loblolly, and longleaf seeds will require a lower germination temperature.

Fluid drilling offers the potential of having every sown seed result in a seedling and extremely uniform seedling development. However, considerable research is still needed to adequately develop all phases of this technique.

7.6.3 *Chemical Treatments*—Many chemicals have been evaluated in a search for a "trigger compound" that can eliminate, quickly and simply, the delayed germination associated with internal dormancy (Bonner and others 1974). There have been limited successes in the laboratory with inorganic ions, organic acids, and growth regulators, especially the gibberellins (Cotrufo 1962, Hatano and Asakawa 1964, Biswas and others 1972), but nursery response has generally been negative. Stein (1965) reported that a 48-hour soak in 1-percent hydrogen peroxide hastened germination of Douglas-fir (*Pseudotsuga menziesii* (Mirb.) Franco) in a field test. The same treatment had little positive effect on sugar pine (*Pinus labertiana* Dougl.) and ponderosa pine (*P. ponderosa* Dougl. ex Laws) germination. A combination of citric acid soaks followed by stratification increased nursery germination of baldcypress (*Taxodium distichum* (L.) Rich.) (Jones 1962). New growth regulator formulations now offer potential for increasing rapidity of seed germination, but these must be subjected to further research. At the present time there is no effective chemical substitute for stratification.

7.7 Disease Problems

In the past, seed fungi on southern pine seeds have not been considered a major concern, because most observations indicated they were saprophytic and did not affect germination (Belcher and Waldrip 1972). With the advent of container culture it has become apparent that seedborne fungi can be an important cause of seedling mortality. Pawuk and Barnett (1974) associated *Fusarium* spp. infection of container-grown longleaf pine seedlings with retention of infested seedcoats. Cotyledons become infected, and the disease spreads down the stem, resulting in mortality.

Many seed lots contain infested seeds. For example, 8 to 20 percent of the seeds from five longleaf seed lots tested for *Fusarium* were found to be infested, and all five species of *Fusarium* recovered were pathogenic on longleaf seedlings (Pawuk 1978). *Fusarium* has since been isolated from seedcoats of shortleaf, slash, and loblolly pine seed (Pawuk 1982). Recent studies show that pathogens may also be present inside pine seeds (Miller and Bramlett 1978). Such infected seeds germinate poorly, and damping-off losses are increased. In addition to *Fusarium*, Mason and Van Arsdel (1978) recently have identified *Trichothecium* as a pathogen on loblolly pine seeds.

Microorganisms infesting conifer seedcoats can be controlled by sterilization or by coating the seeds with fungicides. Many fungicides evaluated for forestry use are phytotoxic (Cayford and Waldron 1967, Vaartaja and Wilner 1956), and sterilants inhibit germination of some species (Neal and others 1967), so both methods have been evaluated with southern pine seeds.

7.7.1 *Sterilants*—Hydrogen peroxide sterilizes seedcoats (Trappe 1961) and also increases germination of some pine seeds (Barnett and McLemore 1967, Carter and Jones 1962). Barnett (1976d) found that a 3-percent solution of hydrogen peroxide reduced infesting organisms on loblolly pine seeds but not on slash, shortleaf, or longleaf seeds. A 30-percent solution virtually eliminated infesting organisms from seedcoats of all four species, but germination was reduced by some soaks (table 7-3).

Short soaks in 30-percent hydrogen peroxide best controlled infestations without reducing germination (table 7-3). Germination of some longleaf seed lots, especially those with low viability, can be increased by a 30- to 60-minute soak, but a preliminary test should be done before soaking an entire lot longer than the recommended time period (Campbell 1982).

7.7.2 *Fungicide Coatings*—Fungicides applied as seed coatings provide a chemical barrier between the germinating seed and soil fungi. Stratified shortleaf pine seed germination and postemergence damping-off were reduced by dusting seeds with 50-percent thiram before sowing (Hamilton and Jackson 1951). The amount of fungicide adhering to seeds can be increased with such adhesives as methyl cellulose or latex. But while fungicides may reduce damping-off (Carlson and Belcher 1969), heavy dosages often reduce germination (Peterson 1970).

Because of the high costs of container production, fungicides must control diseases without sacrificing quick, vigorous germination. The four important southern pine species have different tolerances to funcicides (table 7-4). Loblolly and longleaf seeds are the most tolerant, and slash the most sensitive (Pawuk and Barnett 1979). Shortleaf seeds responded intermediately to the other species.

Captan and thiram (Arasan 42-S®) were the least toxic fungicides. Neither reduced germination of any of the four species, even when applied at 454 g ai/45 kg (16 oz ai/100 lb).

Table 7-3.—*Germination of southern pine seeds soaked for different periods of time of hydrogen peroxide (from Barnett 1976d)*

Hydrogen peroxide	Germination			
	Loblolly	Slash	Shortleaf	Longleaf
treatment	*percent*			
None	91	81	76	53
3 percent				
4 hours	87	82	82	36
8 hours	93	79	80	26
24 hours	93	50	67	27
48 hours	84	43	73	3
30 percent				
1/4 hour	88	83	82	49
1/2 hour	89	85	*75*	63
1 hour	*90*[1]	*84*	48	*77*
3 hours	44	75	7	54

[1] Percentages in italics represent germination at the maximum amount of recommended time.

Table 7-4.—*Maximum fungicide dosages for four southern pines (adapted from Pawuk and Barnett 1979)*

Fungicide[1]	Slash	Loblolly	Shortleaf	Longleaf
	grams ai/45 kg of seed			
Captan 50 WP	454	454	454	454
Arasan® 42-S	454	454	454	454
Terraclor® 75 WP	113	454	454	227
Demosan® 65 WP	113	454	454	227
Truban® 30 WP	57	227	454	454
Banrot® 40 WP	57	114	57	114
Dexon® 35 WP	57	114	57	227
Terra-Coat® SD-205, 25 WP	57	227	113	454
Mertect® 42 F	28	227	113	113
Benlate® 50 WP	28	113	57	57
Busan® 72 60 EC	0	113	57	113
Terra-Coat® L-205, 30 L	0	113	57	113

[1] Common names and chemical names for the fungicides can be found in American Phytopathological Society (1977).

7.8 Sowing Techniques

Sowing rates can be adjusted for poor seed lots. The National Tree Seed Laboratory in Dry Branch, Georgia, will test seed lots for a small fee. Germination tests require 600 seeds, but a complete analysis that estimates stratification requirements takes about 2,500 seeds.

7.8.1 *Number Per Container*—When seed lots have low germination, multiple seeding can reduce the number of vacant cavities. Containers with excess seedlings usually must be thinned. Tables prepared by Balmer and Space (1976) that use sowing rates and expected germination to predict the number of vacant and stocked cavities are useful in selecting sowing rates and in estimating how much thinning will be required.

For example, if germination tests show that expected germination is 70 percent, sowing two seeds per cavity can reduce the percentage of vacant cavities from 30 to 9 percent but will increase doubles to 49 percent. Sowing three seeds per cavity will further reduce vacant cavities to 3 percent but will increase double and triple to 78 percent. To help minimize these problems, Pepper and Barnett (1982) suggest consideration of a mixed sowing scheme. For instance, 30 percent of the containers could receive three seeds, 20 percent of the containers could receive two seeds, and the remaining 50 percent could receive one seed. Mixed sowing schemes are generally more cost-efficient than the standard constant number approach, and the vacuum seeders in use could be adjusted to seed approximately the mix desired. For the nursery manager who wishes to use this method, a user-oriented, interactive computer program is available, which determines an optimal sowing strategy based on the users' estimates of costs and overall germination and survival rates (Pepper and Hodge 1982). However, mixed sowing will still require some thinning and transplanting of germinants to approximate one seedling per container.

7.8.2 *Sowing Methods*—Methods of seed sowing vary from hand seeding or use of simple templates to elaborate electrical seeding devices. However, most container operations now use some type of a vacuum seeder. These consist of a seeding head with holes drilled to match the container arrangement. The head is connected to a vacuum cleaner or pump. Even the most efficient seeders occasionally leave blank containers, so it is desirable to visually check the cavities before the containers are moved to the greenhouse.

7.9 Seed Covering

Covering seeds with granite grit, vermiculite, or potting medium is recommended in many containerized seedling operations (Matthews 1971, VanEerden 1974, Wood 1974) to create a favorable environment for germination by keeping seeds moist, to help radicle orientation, and to reduce development of moss and algae on the medium surface.

The effect of covering southern pine seeds varies with the type of watering regime used and, to some extent, with fungicide coatings (Barnett 1978b). The most complete and rapid germination usually occurs when seeds remain uncovered and are watered by a misting system. When seeds are watered less frequently, covering is helpful in obtaining germination. The data in table 7-5 indicate that larger seeds can be covered to a greater depth than small ones. The beneficial effect of covering seeds that are not under a mist system is probably due to the mulching effect that retains moisture near the seeds.

Fungicide applications to slash seeds reduces germination when under the misting system (table 7-5). Untreated longleaf seeds that were hand watered had a lower germination than all other treatments. This tends to confirm Jorgensen's (1968) finding that thiram coating helps improve germination of covered longleaf seeds. Longleaf may react differently from the other species in this respect because its seedcoats are known to carry pathogenic *Fusarium* fungi (Pawuk and Barnett 1974).

7.10 Transplanting and Thinning Germinants

For maximum efficiency in the production of containerized seedlings, empty cavities must be avoided. Seed germination seldom reaches 100 percent, so containers will have empty cavities after germination is completed. Growers must decide on the best method to increase stocking. Their decision whether to multiple-sow and thin, single-sow and transplant, or to sow and accept initial stocking levels will depend on seed germination, labor costs, and possible long-term effects on field performance. Regardless of the seed sowing regime, there will remain some blank and multiple-sown cavities. Hence, the great interest in operational methods for planting germinated seeds.

Table 7-5.—*Variation in germination due to watering method, depth of cover, and fungicide application (from Barnett 1978b)*

Species	Depth of cover	Fungicide treatment	Watering method[1]	
			Hand	Mist
	mm		*percent*[2]	
Slash	0	Untreated	60[3]	96
		Arasan®	74	85
		A. + latex	64	81
	6	Untreated	80	69
		Arasan	77	50
		A. + latex	72	44
	12	Untreated	67	26
		Arasan	56	26
		A. + latex	58	26
Longleaf	0	Untreated	38	76
		Arasan	61	77
		A. + latex	60	77
	6	Untreated	66	78
		Arasan	82	80
		A. + latex	73	79
	12	Untreated	80	75
		Arasan	81	73
		A. + latex	83	74

[1] Watering method: hand, about 2 times per day; mist, numerous times daily depending on environmental conditions.

[2] Percent germination at 28 days.

[3] Least Significance Difference (LSD 0.05) for germination percentages are 9.2 for longleaf and 21.2 for slash pine.

7.10.1 *Transplanting*—If the percentage of cavities with ungerminated seeds is between 5 and 15 percent, transplanting of germinants from cavities with multiple germinants or from germination flats is a feasible alternate. Up to 5 percent blank cells 4 weeks into the rotation will have little practical effect on costs. If more than 15 percent of the cells are empty, the short fall should be made up by sowing additional containers.

Pawuk (1982) studied the effect of transplanting on initial seedling growth and development. His evaluations involved transplanting germinants with different lengths of radicle development; 1.5 to 2.0 cm, 3.0 to 3.5 cm, and 4.5 to 5.0 cm (0.6 to 0.8 in, 1.2 to 1.4 in, and 1.8 to 2.0 in). All transplanting was done carefully so as to avoid injury to the tender radicles. Earlier observations had shown that damage to the radicle, such as the tip being broken, would slow root development and seedling growth and should be avoided. Transplanting longleaf pine germinants, regardless of their radicle length, was detrimental to subsequent diameter growth compared to nontransplanted controls (table 7-6). Total dry weight of both longleaf and shortleaf pine seedlings at 15 weeks was directly and significantly related to radicle length when transplanted. Control seedlings were heaviest, with the average weight about double that of transplants with short radicles. Heights of shortleaf pine seedlings at 15 weeks were also directly related to radicle length at the time of transplanting, with control seedlings tallest (table 7-6). After transplanting, only seedlings originating from germinants with the shortest radicles were significantly smaller than those from all other treatments.

The importance of careful timing when replacement seedlings are transplanted into empty cavities is clearly shown. Seedlings established by sowing were 1 to 2 weeks older than seedlings established by transplanting. This age difference accounts for the larger size of the control seedlings. Likewise, seedlings from transplants with long radicles were probably older than those from transplants with short radicles. Transplanting should be done as soon as an empty cavity becomes evident. This determination is possible about 10 to 14 days from sowing. At that time, replacements with short radicles would be easier to transplant without damage than seedlings with long radicles. If transplanting is delayed much beyond that time, germinants with longer radicles should be used because smaller seedlings are quickly suppressed at dense stockings.

7.10.2 *Thinning*—If cavities are multiple-sown, then a decision on whether or not to thin must be made. Thinning should be completed as soon after germination occurs as is feasible to minimize the effects on seedling development.

The short-term effects of leaving multiple seedlings in container cells have been evaluated with longleaf, loblolly, and slash pine (fig. 7-5). The most marked effect was on seedling development, measured as dry weight at the end of the 14-week greenhouse growing period, where multiple seeding reduced seedling dry weights by one-half or more. The smaller, multiple-grown seedlings had poorer survival compared to those grown with only one seedling per cavity.

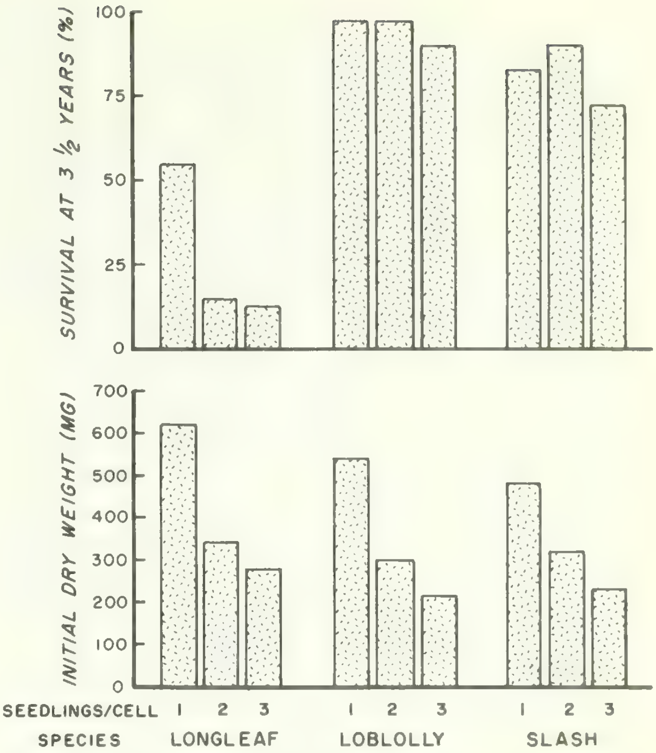


Figure 7-5.—*Initial seedling development 14 weeks after sowing in Styroblock-4 containers and field performance after 3-1/2 years.*

Longleaf pine seedlings were more seriously affected by multiple seeding than loblolly or slash seedlings. The effects of multiple sowing were less drastic with slash and loblolly pine. But even with these species, initial seedling development was reduced by multiple seeding if no thinning occurred. Although there are no significant size differences among treatments after 3 years in the field, differ-

Table 7-6.—*Effect of radicle length at time of transplanting on growth of longleaf pine and shortleaf pine seedlings after 15 weeks (adapted from Pawuk 1982)*

	Longleaf pine		Shortleaf pine	
Radicle length	Root-collar diameter	Dry weight	Height	Dry weight
cm	*mm*	*mg*	*cm*	*mg*
1.5 - 2.0	1.12 a	168 a[1]	8.61 a	137 a
3.0 - 3.5	1.20 a	210 b	9.36 b	173 b
4.5 - 5.0	1.28 a	237 c	9.48 b	188 b
Seeded (control)	1.48 b	342 d	9.93 b	280 c

[1] Means in vertical columns followed by the same letter are not significantly different.

ences become greater each year, i.e., slash seedlings in the one-per-cavity treatment were 3 percent taller than in the three-per-cavity treatment after 1 year but 8 percent taller after 3 years in the field.

No long-term data are available on the effects of planting containers with multiple seedlings; however, results from 15-year-old multiple-seeded spots in direct seeding tests give an indication of the effects (Campbell 1983). Leaving two or more seedlings per spot caused a significant reduction in height and diameter. The effects on container plantings will be even more adverse, because with multiple seedlings per container, each seedling is smaller when outplanted than where there is a single seedling per container.

As a general recommendation, the grower should (1) use only the best quality seed available, (2) thin multiple seedlings to one per container, and (3) transplant only vigorous germinants. Both thinning and transplanting should be completed as soon as possible.

8. GREENHOUSE ENVIRONMENTAL CONTROLS

Detailed descriptions of greenhouse equipment and facilities to maintain specified environmental conditions for germination and seedling growth will not be given here. Tinus and McDonald (1979) have provided this information. However, the environmental conditions resulting in best germination and seedling performance will be reviewed for the southern pine species.

8.1 Germination Period

Germination depends on adequate light, moisture, and favorable temperatures. The lack of optimum conditions for germination can be offset in some species by lengthening the stratification period. For example, loblolly pine germination is more prompt and complete under simulated field conditions (16 °C [60 °F], 11-hour photoperiod) when the stratification time is increased from 30 days to 45 or 60 days.

8.1.1 *Light*—It has been well documented that southern pine seeds require light for germination (Nelson 1940, Toole and others 1962, McLemore 1971). However, the intensity of light is relatively unimportant. Slash and loblolly pine seeds germinate as well at 1600 lux (150 footcandles) as at 3200 lux (300 footcandles)(Jones 1961). It is the length of the light period that is important. When the photoperiod is increased from 8 to 16 hours, germination of loblolly pine seeds increases (fig. 8-1), but slash pine germinates about the same under 8-, 12-, and 16-hour light exposures. The adverse effect mentioned in section 7.9 of deep covering on germination is probably largely due to the lack of sufficient light penetration of the medium (Barnett 1978b).

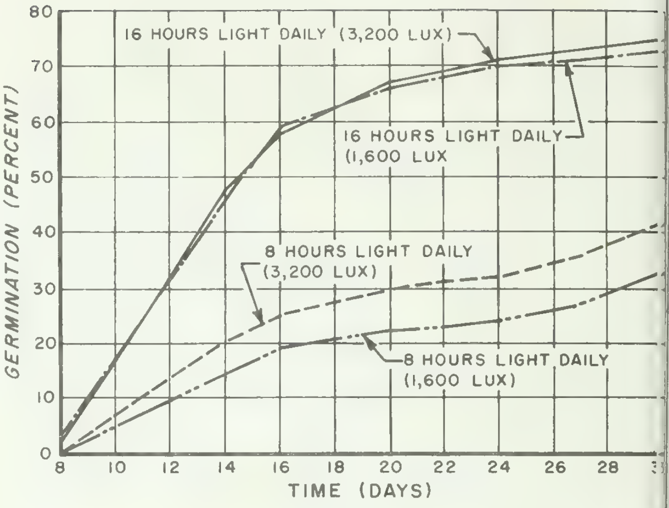


Figure 8-1.—*Germination of loblolly pine seed under 8-hour and 16-hour light regimes and two light intensities (from Jones 1961).*

The quality of light can be an important consideration. Wave lengths in the red spectrum (660 nm) are known to promote germination of southern pine seeds while those of the far-red (730 nm) length inhibit germination (Toole and others 1962, McLemore 1971 McLemore and Hansbrough 1970). The red wave lengths are in sufficient quantity in sunlight, incandescent, and fluorescent light, so artificial lighting has no detrimental effect on germination.

8.1.2 *Moisture*—Containers must be watered frequently during the germination period. The watering system must keep the seeds in contact with a moist medium. When using a misting system, the mist should not be so light as to allow the potting mixture to dry at the bottom of the container. The condition o the sky, outdoor temperatures, and location in th greenhouse will affect the frequency required t maintain an ideal condition for germination. Fo these reasons, controls for watering systems that reflect environmental changes, such as the Mist-A-Matic® control (Geiger 1960), are more desirable tha time clocks that water on a predetermined schedule regardless of need. If there are considerable minerals in the water, controllers must be cleaned frequentl with acid to avoid calibration changes.

During the germination period, it is important that the moisture content of the potting mixture remains near field capacity. Any moisture stress beyond −2. bars (−250 kPa) reduces germination of southern pines (Barnett 1969b). Germination of longleaf pine better than slash pine seeds at moisture stresses of − to −14 bars (−800 to −1400 kPa).

8.1.3 *Temperature*—Even though Wakeley (1954 suggests some limits for germination of the major southern pines, definite temperature effects are not known. McCulley (1945) did note that temperatures above 27 °C (80 °F) were detrimental to germination of longleaf pine seeds. Knowledge of the maximum temperatures for germination of pine seeds becomes a necessity because of the need to germinate seeds under greenhouse conditions where temperatures may be quite high.

Germination responses of southern pine seeds to temperature vary by species, seedlot, and the use and length of stratification (Barnett 1979b). Longleaf pine seeds have no stratification requirement, but unstratified seeds germinated well only at 18 °C (65 °F) and 24 °C (75 °F), (fig. 8-2). The responses of loblolly, slash, and shortleaf seeds to temperature are similar (fig. 8-2). The temperature at which unstratified seeds of the three species reached peak germination was 24 °C (75 °F). Unstratified slash pine seeds were less affected by temperature extremes than loblolly or shortleaf seeds. Slash pine seeds have a wide range, 18 to 29 °C (65 to 85 °F), at which germination was greater than 70 percent, the generally accepted minimum.

For loblolly, slash, and shortleaf seeds, stratification for either 28 or 56 days widened the range of temperatures at which a fairly uniform plateau of satisfactory germination occurred.

Because the above data were obtained under standard laboratory conditions with constant temperatures, these results cannot be applied directly to greenhouse conditions where temperatures fluctuate from day to day and during a 24-hour period. Additional evaluations were made with fluctuating temperatures that were more representative of greenhouse conditions. Longleaf pine was the only one of the four species that was adversely affected by temperatures alternating between 24 °C (75 °F) and 35 °C (95 °F) (table 8-1). These tests indicate that daily short periods of high temperatures may not reduce seed germination. Dunlap and Barnett (1982) found that exposures of loblolly and shortleaf seeds to periods of 35 °C (95 °F) up to 12 hours per day speeded germination without adversely affecting total germination. However, longleaf germination was reduced by this high temperature exposure.

8.2 Postgermination Period

8.2.1 *Light*—Photoperiod can either be lengthened or shortened, depending on the type of facilities available. Extending the photoperiod by the use of low-intensity light at intermittent intervals generally produces larger seedlings during the winter months when natural photoperiods are relatively short. Early bud set is prevented and longer internodes, increased size of foliage, and early change from primary to secondary needles can result from extending the photoperiod.

Limited data are available on the amount of response with southern pines from extended photoperiods. However, ponderosa pine seed sources from a latitude of 33° N, which is about the latitude of Dallas, Texas; Jackson, Mississippi; and Savannah, Georgia; are quite photosensitive (Tinus 1977). Both height growth and seedling dry weights were increased by treatments where the photoperiod was extended by incandescent lighting for 1 minute out of every 30

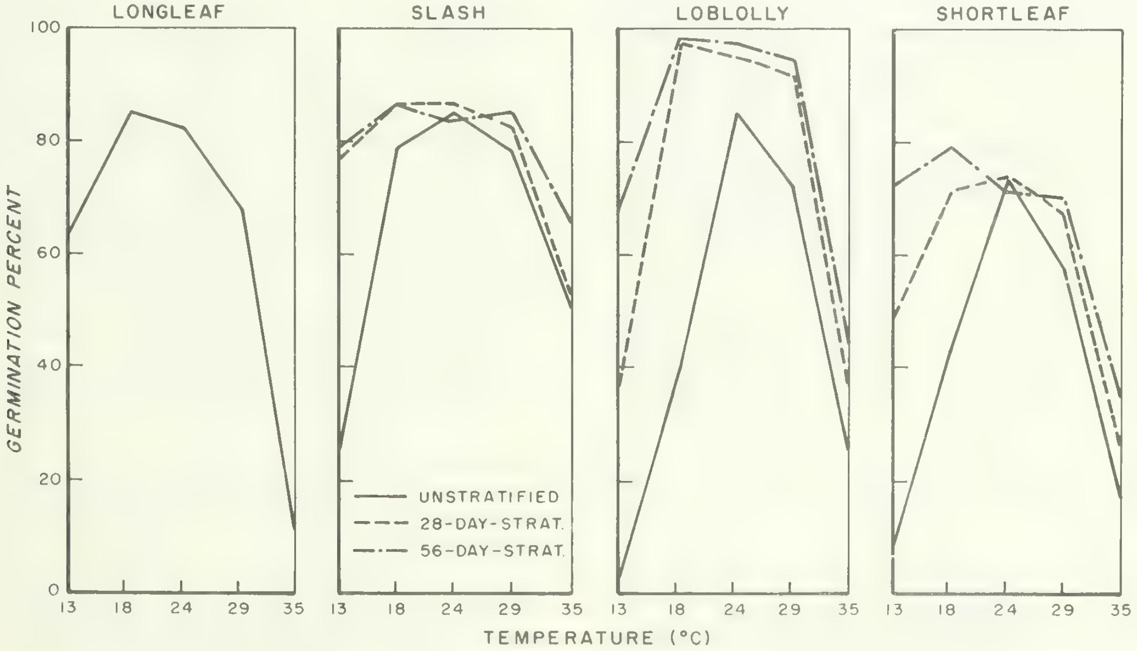


Figure 8-2.—*Germination of southern pine seeds at five temperatures following pregermination treatments (adapted from Barnett 1979b).*

Table 8-1.—*Germination of southern pine seeds at various temperature regimes*

Species	Seed stratified	Germination at Constant 24 °C	Germination at 24–35[1]	Germination at Constant 35 °C
		percent	*percent*	*percent*
Longleaf	No	79 a[2]	61 b	12 c
Slash	No	84 a	83 ab	71 b
	Yes	80 a	72 ab	66 b
Loblolly	No	88 a	89 a	27 b
	Yes	97 a	96 a	46 b
Shortleaf	No	78 a	76 a	42 b
	Yes	46 a	45 a	30 b

[1] 18 hours at 24 °C and 6 hours at 35 °C.

[2] Means within species stratification treatments (across rows) followed by the same letter are not significantly different at the 0.05 level.

during the night at intensities of 270 lux (25 footcandles). One minute out of every 30 at 270 lux was as efficient at maintaining growth as continuous light at 1,200 lux (112 footcandles) (fig. 8-3). Height growth and dry weight of this southern source of ponderosa pine were found to be less dependent on long days than more northern sources of the same species (fig. 8-3, 8-4).

It is not necessary to have continuous light for extending the photoperiod. Having lights on for as little as 3 percent of the time during the night is effective provided that no dark period is longer than 30 minutes. Although photosensitivity varies somewhat by species, light intensities of 430 lux (40 footcandles) are generally sufficient (Tinus 1977).

Although lengthened days are important in preventing bud set and in maintaining seedling growth during the short photoperiods of winter, short days are important in developing cold hardiness. Some growers shorten the photoperiod by covering seedlings with black cloth part of each day during late summer or early fall. This technique stimulates early bud set and frost hardiness, but is difficult to do on a large scale. Reductions in both irrigation and fertilization are the most common techniques used for inducing seedling dormancy (see section 9.10). Frost hardiness can also be promoted by exposing seedlings to cool temperatures after buds develop.

The use of high-intensity light to increase photosynthesis for better growth in the short-photoperiod winter months is biologically feasible, but it has become impractical from an energy standpoint. Minimum light intensity necessary to produce good growth from increased photosynthetic activity is about 5,400 to 10,800 lux (500 to 1,000 footcandles) (Tinus and McDonald 1979).

Several types of lighting are now available for greenhouse operations. A combination of cool-white fluorescent and incandescent lamps has been considered the best to supplement sunlight in greenhouses. Recent work has shown that high intensity discharge lamps such as the sodium type are more effective for starting plants (Anon. 1977b). However, this type of lighting is advantageous only when the purpose of the supplemental light is to increase growth by maintaining high light intensities. They are not suitable for cyclic lighting because they require 5 minutes to start and cannot be conveniently used in short-duty cycles (Tinus and McDonald 1979). For extending the photoperiod, incandescent lamps provide the desired spectral qualities, are inexpensive to install, and can be turned on and off frequently without loss of bulb life. Incandescent lamps are not as economical to operate as some other types of lamps, but their other characteristics make them advantageous.

8.2.2 *Moisture*—Overhead spray systems are the most frequently used watering system for commercial growth of tree seedlings. Fixed overhead sprinklers

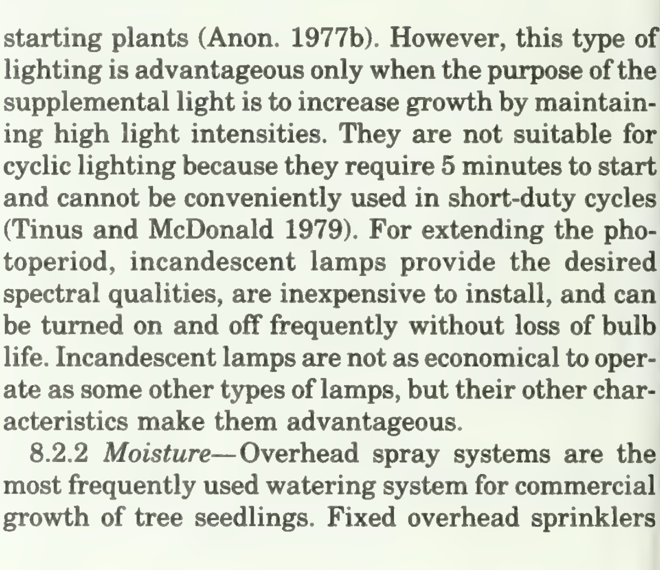


Figure 8-3.—*Height growth response of ponderosa pine from Valentine, Nebraska, and Ruidoso, New Mexico, to different durations of continuous incandescent light at night at 1,200 lux (A) and different intensities of incandescent light given 1 minute out of every 30 throughout the night (B) (adapted from Tinus 1977).*

are the most common and consist of four types—fixed overhead, rotating, oscillating, and spray stake. The main problem of the fixed systems is lack of uniform coverage. Traveling boom units generally result in more uniform coverage. They are also much more expensive. Because of the lack of uniform drying conditions, some supplemental hand watering will be necessary with almost any watering system.

An important part of the watering system is a feeder mechanism for applying nutrients, fungicides, and other chemicals. Several types are available and the size of operation and type of watering system influences selection of the feeder. Proportional feeders with water-to-chemical ratios of 100:1 to 200:1 are commonly recommended.

The method of watering during the postgermination period differs from that used during germination. Heavy, infrequent waterings should characterize the postgermination period (see section 9.1.1). This allows the surface of the medium to dry between waterings and reduces the chance of damping-off. Less frequent waterings also reduce the water content of the medium, which increases the amount of aeration, absorption of minerals, and root growth.

8.2.3 *Temperature*—Extremes in temperature are not much of a problem once the seedlings become several weeks old. Because greater fluctuations in temperature can be tolerated once seedlings begin rapid growth, less environmental control of the greenhouse facilities is required. During the frost-free period of the year (see section 4.1.3), southern pine seedlings 4 to 5 weeks old can be moved into nonenvironmentally controlled facilities for the remaining period of growth. Generally these facilities should be covered with transparent fiberglass or something similar so that the amount of water the seedlings receive can be controlled.

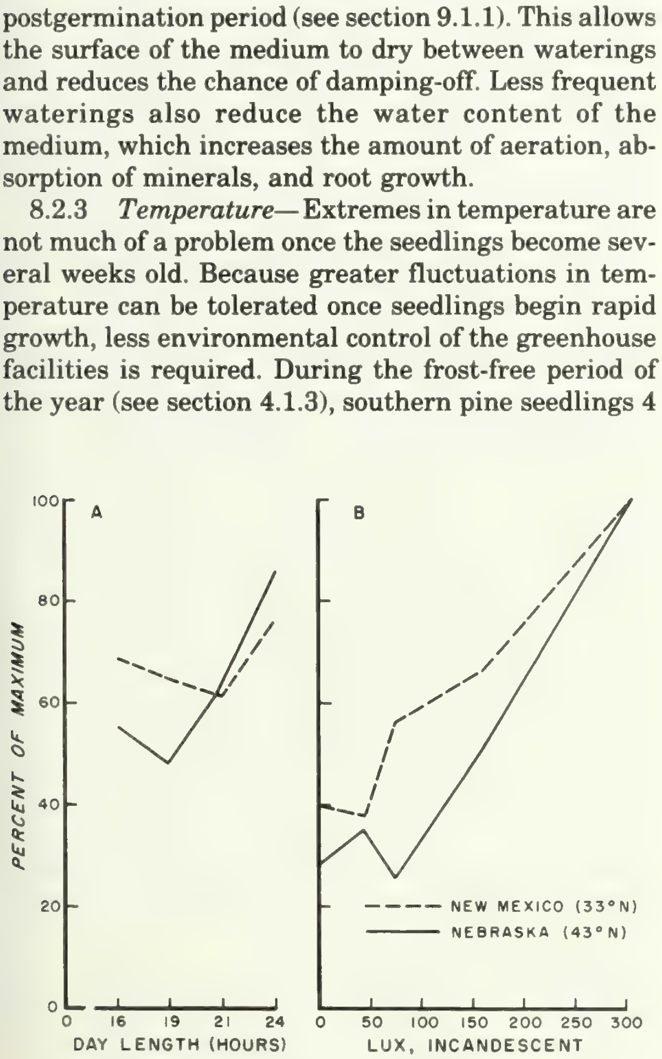


Figure 8-4.—*Dry-weight growth response of ponderosa pine from Valentine, Nebraska, and Ruidoso, New Mexico, to different durations of continuous incandescent light at night at 1,200 lux (A) and different intensities of incandescent light given 1 minute out of every 30 throughout the night (B) (adapted from Tinus 1977)*

If seedlings are to be produced during the winter, a heated greenhouse will be required. Heat can be provided either overhead or under the seedling benches. Greenhouses must also be cooled during warm weather to provide optimum growing temperatures. The evaporative cooling that is most often used in greenhouses utilizes exhaust fans and wetted pads or lava rock; shading can also be used to help maintain cooler temperatures. Tinus and McDonald (1979) provide a thorough discussion of various sytems of greenhouse heating and cooling. The cultural and economic aspects of various greenhouse energy conservation measures are discussed by Cameron (1982).

8.2.4 *Carbon Dioxide*—Carbon dioxide (CO_2) is necessary for plant growth. The ambient level of CO_2 in the atmosphere is about 325 ppm. Tinus (1972) has shown that CO_2 enrichment up to about 1,500 ppm can result in increased plant growth. Raising the CO_2 level above the ambient level can be accomplished in a greenhouse by burning natural gas or propane, and small CO_2 generators are readily available from nursery supply houses. However, it is practical and efficient to raise the CO_2 concentration only during daylight hours and only when the greenhouse vents are closed (Tinus and McDonald 1979). This limits CO_2 generation to periods during the winter months when greenhouse venting systems remain closed due to cold weather. Fortunately this is when growth is normally the slowest and thus the need for growth stimulation is the greatest. The usefulness of increasing CO_2 levels has not been demonstrated in the southern latitudes, probably because climatic conditions limit the amount of time the technique is practical. However, CO_2 generation is fairly inexpensive and it may be practical for a few morning hours each winter day. Tinus and McDonald (1979) describe several ways to generate CO_2. The most practical is an inexpensive gas generator (fig. 8-5). For a greenhouse of average tightness, 245 joules of gas burned per square meter (2.5 Btu/ft^2) of greenhouse space yields about 1,000 ppm CO_2.

9. CULTURAL TECHNIQUES

Many of the cultural techniques necessary to optimize growth of the southern pines remain to be refined. However, sufficient information is available to produce high quality seedlings in a reasonable length of time.

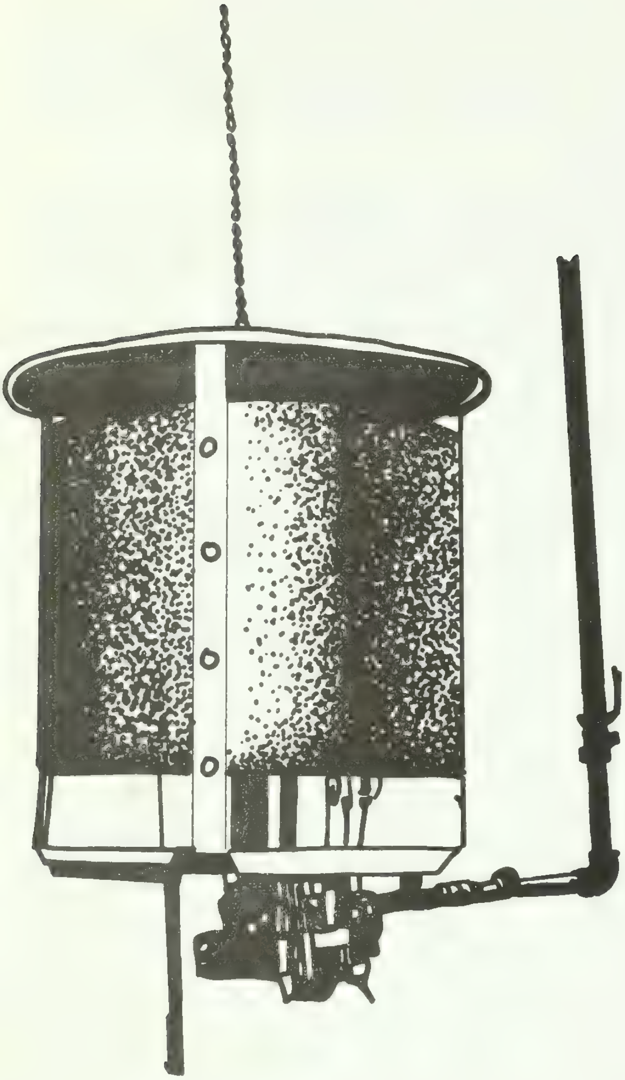


Figure 8-5.—*Inside ceiling-mounted gas CO_2 generator (from Ekblad 1973).*

9.1 Maintaining Proper Moisture and Temperature

One of the most critical factors in the day-to-day growing operation is maintaining proper moisture of the potting medium.

9.1.1 *Moisture Content for Optimum Growth*—The watering schedule should keep the moisture contents of the potting medium near field capacity at all times during the active growing phase. This will result in optimum growth if other factors such as nutrients or temperatures are not limiting. An important consideration in watering is aeration of the medium. The mix texture itself determines how much oxygen is available for root respiration at a particular watering level—larger sized particles increase porosity.

The symptoms of poor aeration, which is caused primarily by overwatering, include needle chlorosis, inhibition of shoot and root growth, and even death when overwatering is severe and prolonged (Kozlowski 1975).

The effects of different moisture levels on development of loblolly and longleaf pine seedlings were determined by measuring root and shoot dry weights after a 10-week growing period (fig. 9-1). The seedlings were grown in 6-inch plastic pots filled with a 1:1 peat-vermiculite medium. Different moisture levels were maintained by weighing the pots and adding sufficient water twice weekly to keep the media near the prescribed moisture levels. Moisture contents between 300 and 500 percent (dry-weight basis) resulted in the best seedling development. Moisture contents higher or lower than this adversely affected seedling growth. Generally, shoot-root ratios increased as the moisture content of the potting medium increased. Such gravimetic measurements are too time consuming for everyday use, but they are very helpful when calibrating other methods.

Medium moisture content can readily be evaluated using the weighing method (McDonald and Running 1979). Weighing seedling containers is a useful irrigation monitoring practice. When the weight of a filled container declines to some predetermined percentage of the saturated weight, the crop is watered. This percentage is often around 75 to 80 percent of the saturated weight, depending on the type of container.

Once the seedlings become large, the pressure chamber is the quickest, most foolproof method of measuring water stress in seedlings (Scholander and others 1965). A sample seedling is cut at the root collar and placed in a steel chamber with the cut end protruding from the top (fig. 9-2). By slowly applying pressure to the seedling in the chamber, water will be forced back to the cut surface by a pressure equal to the tension originally in the plant.

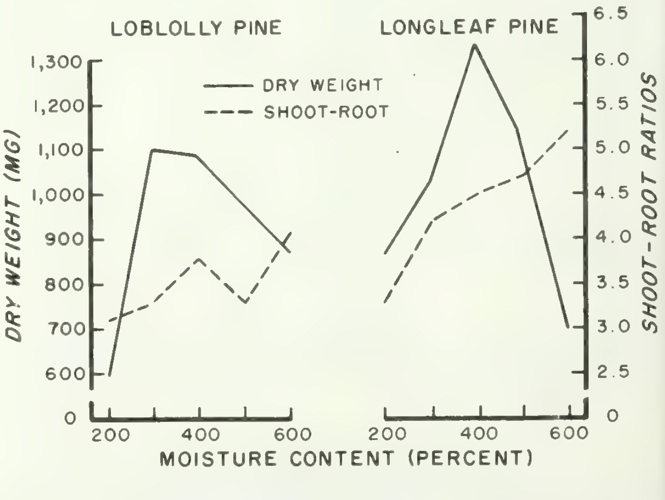


Figure 9-1.—*Oven-dry weights and shoot-root ratios of loblolly and longleaf pine seedlings grown at various moisture levels of the potting medium (1:1 peat vermiculite).*

Certain precautions are important when using the pressure chamber (McDonald and Running 1979). First, the sample should be measured within 1 minute or wrapped in a wet paper towel and sealed in a plastic bag until measured. Second, the pressure should be increased slowly at about 1 bar (15 lbs/in^2) per 5 seconds. Third, it is best if the size of the cut sample is consistent. Fourth, the cut end should not protrude more than 1 cm (0.39 in) from the gasket. See section 9.10.1 for further details on water stress relationships.

9.1.2 *Temperatures*—Many studies have involved a search for specific optimum temperatures for growth. The complex relationships between temperature and growth makes the determination of optimum temperatures difficult to pinpoint. Heat energy is not used directly by plants for growth, but controls the rate at which chemical energy is made available for growth (Went 1957). The relationship is further complicated, because growth is a result of a multitude of processes that are undoubtedly affected somewhat differently by particular temperatures. Various phases of a temperature regime have been found to affect growth, such as day and night temperatures and the differences between them. Information available on how the relationships affect growth of southern pines is limited. Kramer (1957) subjected 1-year-old loblolly seedlings to various day and night temperature combinations. He reported that growth of shoots increased with increasing day temperature and decreased with increasing night temperatures. The difference between day and night temperatures appeared to be the most important factor. His seedlings were tallest when the difference was about 12.5 °C (22 °F) and shortest when there was no difference between day and night temperatures.

Perry (1962) also reported a general increase in height growth of loblolly seedlings with increasing day temperature. Growth with a day temperature of 23 °C (74 °F) was lowest when the night temperatures were in the range of 20 to 26 °C (68 to 79 °F) and highest for nights in the 10 to 17 °C (50 to 63 °F) range. In one of the most extensive studies of temperature effects on loblolly seedling growth, Greenwald (1972) took data at 6 and 9 months of age on height and shoot and root dry weights. His results indicate maximums in height, shoot dry weight, and total dry weight when the day temperature ranged from 17 to 26 °C (63 to 79 °F) and night temperature ranged from 17 to 23 °C (63 to 73 °F). The 23/17 °C (73/63 °F) day/night degree combination produced maximum height growth and shoot dry weights, with a rapid decrease through 26/20 °C (79/68 °F) to a low value at the 29/23 °C (84/73 °F) combination.

Results by Mulroy (1972) and Bates (1976) with younger seedlings of loblolly pine indicate that the temperature relationships may differ with seedling age. Young plants in warmer greenhouses grew more rapidly, elongated earlier, and had longer stems. Bates (1976) suggests that containerized loblolly seedlings grown for periods of about 12 weeks should be grown for 4 to 6 weeks at the warmest combination (29/23 °C or 84/73 °F day/night temperatures), followed by 26/20 °C (79/68 °F) or 26/17 °C (79/63 °F) regimes for the remainder of the greenhouse period. This would take advantage of the fast start, but would reduce shoot growth while maintaining high total weight production. However, none of the day/night temperatures were clearly superior in producing containerized loblolly seedlings.

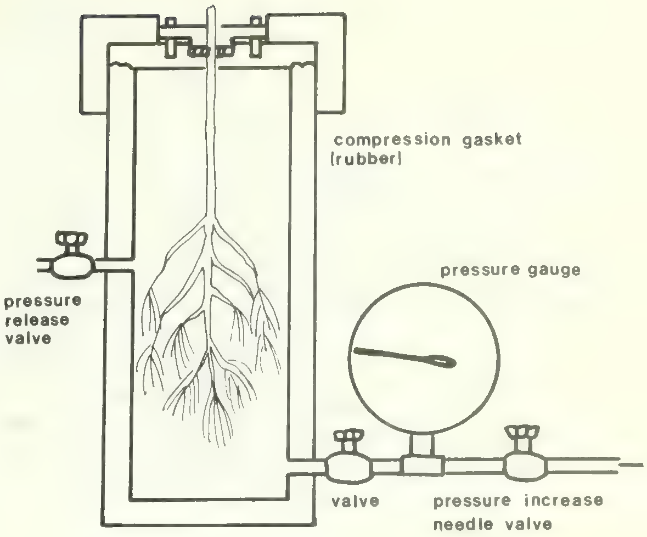
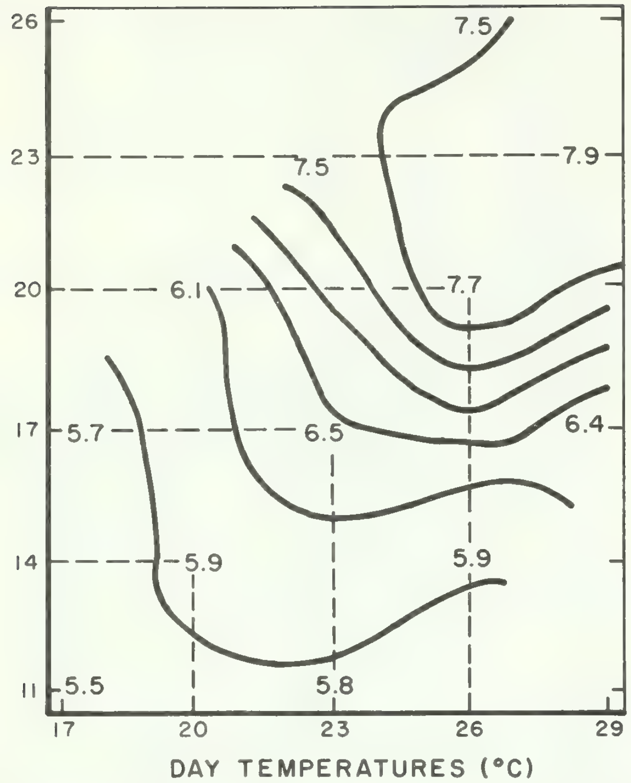


Figure 9-2.—*Diagram of a pressure chamber (modified from McDonald and Running 1979).*

Bates (1976) has reported the effects of varying day/night temperature combinations on development of container-grown longleaf pine seedlings. He evaluated the effects of the temperature combinations at 30 and 60 days. Results from the 30-day evaluations indicated that shoot growth and total dry weight increased with both day and night temperature, especially when the temperature difference was 6 degrees (fig. 9-3 and 9-4). The 26/20 °C (79/68 °F) and 29/23 °C (84/73 °F) regimes produces the tallest shoots. The 23/17 °C (73/63 °F) combination resulted in high dry weights.

The results of Bates' (1976) evaluations of 60-day longleaf seedlings followed the same trends, except there was a tendency to shift away from the highest day temperatures and toward the 23 °C (73 °F) days for greatest shoot growth (fig. 9-5). The 23/17 °C (73/63 °F) regime produced the greatest total dry weight (fig. 9-6) and appeared to be the best combination for growing containerized longleaf seedlings. This temperature regime favored development of all the desired characteristics for successful handling and



igure 9-3.—*Computer generated contours of longleaf seedling heights in cm for each discrete temperature combination (sampled at 30 days); the range within each contour is 0.336 cm.*

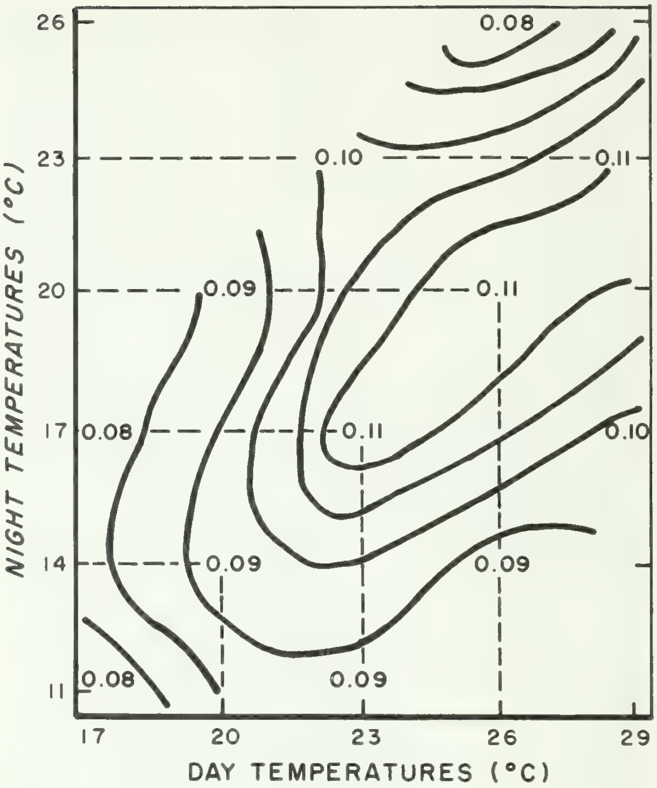


Figure 9-4.—*Computer generated contours of longleaf seedling total dry weights in grams for each discrete temperature combination (sampled at 30 days); the range within each contour is 0.0052 g.*

lanting. While warmer temperatures resulted in bet- er top appearance, weaker and finer roots were pro- uced.

Between 6 and 10 weeks of age, optimum day tem- eratures for longleaf seedlings shifted from 29 °C 84 °F) to 23 °C (73 °F). The 23/17 °C (73/63 °F) regime vas the best overall combination.

The optimum temperatures for containerized oblolly seedlings according to Bates' (1976) work is a 9/23 °C (84/73 °F) day/night regime. This is quite ifferent from the data of Greenwald (1972), who mea- ured seedlings more than 6 months old. The differ- nces between these results may be due to changes in nvironmental responses during seedling develop- nent. Apparently, as seedlings develop there is a shift n the temperatures that are optimum for growth.

.2 Disease Control

Pathogens that cause diseases of southern pine eedlings in bare-root nurseries can cause similar dis- ases when seedlings are container-grown. Fortu- ately, not all diseases found in bare-root nurseries ave been problems in container seedling culture. The reenhouse environment in which most container eedlings are grown differs greatly from the bare-root nursery, and disease development in container nurseries may be more rapid and intensive. Also, the relatively high cost of carrying blank cells makes disease loss more serious on a seedling basis than in bare-root nurseries, where some seedling losses are accepted.

While the greenhouse environment can create problems, the nursery manager is able to control the environment much more than when seedlings are grown outside. He can regulate temperature, humidity, soil moisture, and soil fertility to a great extent. Pesticides can be applied effectively to control diseases and insects.

To control disease losses, a thorough understanding of the pathogens and the conditions necessary for infection is essential. The problems of seedborne diseases are probably greater in greenhouse operations than in nursery beds. These diseases and their control were discussed in chapter 7. The discussion here includes diseases commonly referred to as damping-off or root rot, caused by fungi present in the growing media. It includes those that may in a strict sense be water-borne, being introduced into the soil by contaminated irrigation water.

9.2.1 *Soilborne Diseases*—Species of *Fusarium*, especially *F. moniliforme*, are the fungi most commonly cultured from diseased seedlings and growing media

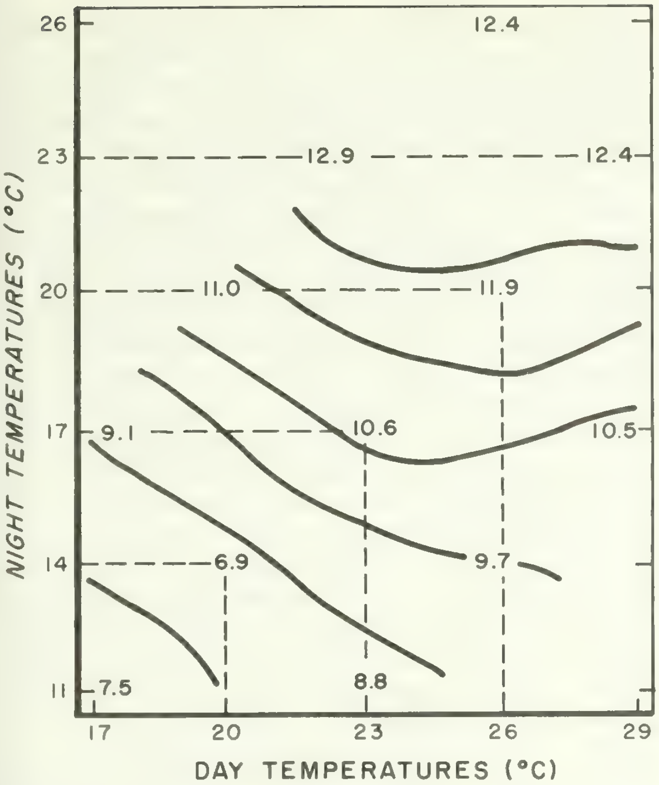


Figure 9-5.—*Computer generated contours of longleaf seedling height in cm for each discrete temperature combination (sampled at 65 days); the range within each contour is 0.77 cm.*

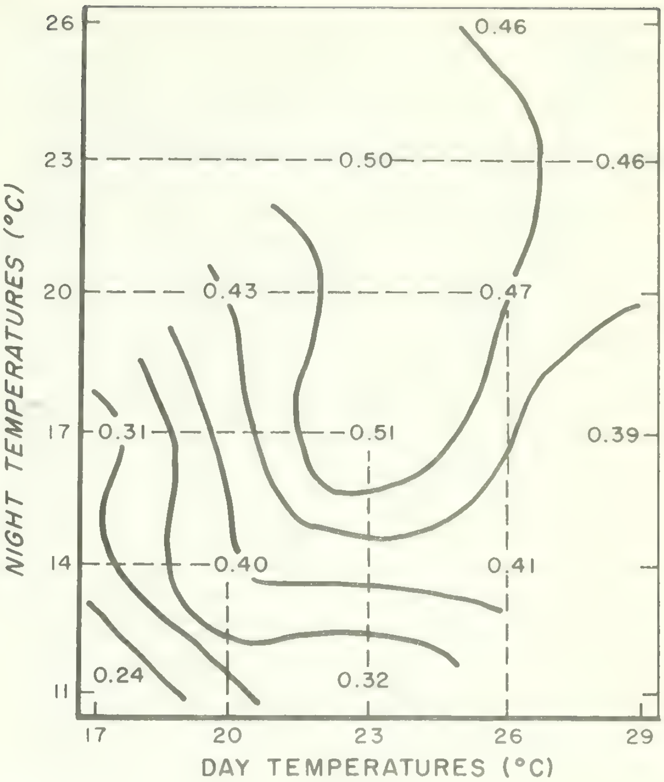


Figure 9-6.—*Computer generated contours of longleaf seedling total dry weights in grams for each discrete temperature combination (sampled at 65 days); the range within each contour is 0.038 g.*

(Pawuk 1982). Attempts to culture *Fusarium* from potting mixes prior to sowing have been unsuccessful. This indicates that it becomes established and develops after containers are placed in the greenhouse.

Pawuk (1982) cultured *Fusarium* from air and water samples in and around greenhouses, but always at low levels. While these sources cannot be ruled out, spread from infected seedlings during watering is probably the most important source. *Fusarium* can often be seen producing abundant spores on infected seedlings. It spreads to the soil where there is a buildup of *Fusarium* with time. Fortunately, seedlings become more resistant to infection as they mature.

Rhizoctonia has been observed on container-grown longleaf pine seedlings. In all cases it developed during periods when seedling foliage was wet for extended periods. Its spread is from seedling to seedling, and the mycelium is clearly visible. The source of *Rhizoctonia* is not known. It is a common soil fungus that spreads in nature by movement of infected soil or plant debris from one area to another. It could easily be brought into greenhouses, as could other soil fungi, by workers or on tools and equipment. *Rhizoctonia* has been observed attacking seedlings in germination trays in the seed testing lab (Pawuk 1982).

Water molds such as *Pythium* and *Phytophthora* may enter container nurseries through contaminated irrigation water or by methods previously mentioned. They are favored by wet, poorly drained soils and cause root rot and damping-off of young seedlings. As seedlings mature, they become more resistant, but root development and seedling growth can be reduced.

Some cultural practices can go a long way toward preventing disease loss. Media should be pathogen free from the start. It should be well drained and seedlings should not be overwatered. Equal parts of peat and vermiculite can be mixed to make a growing medium that combines high cation exchange capability, good moisture retention, and low pH (Phipps 1974). Commercial media are available but most of these were developed for other crops and have a high pH. Growth may be acceptable, but disease development is favored.

Inoculation studies on longleaf seedlings by Pawuk (1981) using *Pythium* and *Fusarium* compared disease development using several media. The best growth of seedlings was with equal parts of peat and vermiculite (table 6-1). Less growth but better disease control was achieved using pine bark, pine bark-vermiculite, or pine bark-soil (see section 6.1). Commercial peat-vermiculite, or pine bark-vermiculite mixes that have higher pH's, had the greater disease incidence.

9.2.2 *Fungicide Treatments*—Several fungicides are available that will control damping-off and root rot if applied correctly. There is no one fungicide cure-all that gives protection against all pathogens.

Pawuk (1982) tested several fungicides for control of *Fusarium* and *Pythium*. The best results were with Benlate® for *Fusarium* and Truban® for *Pythium* at rates recommended on the labels. When applied correctly, they give good disease control without phytoxicity.

During studies with Benlate, applications were made immediately following sowing, with no loss in germination. Truban was not tested this way because it had been found to reduce early seedling development in previous studies (Pawuk and Barnett 1974).

Fungicides affect mycorrhizal development. Responses vary with fungicides and mycorrhizal symbionts. Not much work has been done with southern pines, but some data are available. Pawuk and others (1980) tested the effect of several fungicides on the development of ectomycorrhizae on longleaf seedlings grown in pine bark media. The mycorrhizal fungus, *Pisolithus tinctorius* (Pers.) Coker and Couch was completely inhibited by Terraclor®, reduced by Captan® and Dexon®, not affected by Mertect® and Truban, and stimulated by Benlate and Banrot®. *Thelephora terrestris* (Ehrh.) Fr. was greater on seedlings drenched with Banlate, Mertect, and Dexon than on the control. Terraclor and Truban reduce *T. terrestris*. Seedlings drenched with Terraclor had poor lateral root development suggesting that repeated use of this fungicide should be avoided in container nurseries.

Additional tests found that shortleaf pine seedlings grown in peat-vermiculite and drenched with Benlate formed more mycorrhizal roots than undrenched seedlings (Pawuk and Barnett 1981). *Pisolithus* formed best at the highest level tested, 10 mg of Benlate per seedling every 2 weeks, which also produced the largest seedlings.

Marx and Rowan (1981) reported that drenches of Benlate and Captan increased mycorrhizal development by *P. tinctorius* and *T. terrestris* on loblolly pine seedlings in a bare-root nursery. Terraclor had no effect on either symbiont, but Benodanil® decreased infection by *P. tinctorius*. In this study, two drenches were made in early spring, so the effect of repetitive dosages was not tested.

9.2.3 *Foliage Diseases and Rusts*—Foliage diseases have not been a problem on container-grown southern pine seedlings. This is probably due to the short period necessary to grow plantable seedlings and to the absence of prolonged periods when foliage is wet. The same can be said for the rusts, although, even if seedlings were infected with *Cronartium* rusts, the symptoms would probably not be observed before they were shipped.

It is a good idea to take certain precautions that should keep the probability of rust infections to a minimum. Spraying with fungicides to prevent rust infection is not necessary in closed greenhouses. However, during the spring, seedlings should be watered early in the day so foliage is dry by night. This is especially true during wet weather when rust spores are released. Pawuk (1982) observed rust infection on slash pine seedlings in an experimental greenhouse in Louisiana. Seedlings were purposely watered in the evening so foliage would be wet during the night to favor rust infection. Infection was only 3 percent compared to 65 percent for seedlings similarly treated and grown in an adjacent open shade house. The low rate of greenhouse infection was probably due to the absence of sufficient inoculum, since air movement into the greenhouse was minimal. As long as the foliage remains dry, and greenhouses are closed at night, rust should not be a problem. When container seedlings are grown or held outside, seedlings should be sprayed to avoid rust infection.

The systemic fungicide Bayleton® (triadimefon) is effective for control of fusiform rust caused by *Cronartium quercuum* (Berk.) Miyabe ex Shirai f. sp. *fusiforme* (Cumm.) Burds. & Snow in pine tree nurseries. Bayleton has been tested as foliar sprays and seed soaks on pine for both protective and curative control of fusiform rust (Mexal and Snow 1978, Snow 1978, Snow and others 1979).

Normally, seedlings are susceptible to fusiform rust during the rust hazard season from early March until the first week in July. However, foliar sprays of Bayleton effectively control fusiform rust whether applied 2 weeks before or 2 weeks after inoculation (Rowan 1982).

9.3 Algae Control

Many blue-green and green alga species form on soil in containers used for growing containerized southern pine seedlings (Barnett 1978c). Ross and Purtich (1981) determined that most of such contaminants are not in the medium or water, but are airborne. When algae develops and dries, a crust develops, creating a barrier that interferes with irrigation, fertilization, and pesticide applications (Tinus and McDonald 1979). One effective algae control is a perlite or grit covering on the surface of the growing medium. However, this may affect seed germination (section 7.9), and chemical control of algae may be desirable.

Chemicals that control algae in water or on the surface of the potting soil are not labeled for soil treatments, so the greenhouse manager has no guidelines for selecting appropriate chemicals to treat the soil. A greenhouse screening study evaluated 11 substances for controlling algae on soil in styrofoam containers used to grow shortleaf pine (table 9-1) (Pawuk 1983).

Algae formed a thick mat on soil in control plots and many treatment plots. Simazine® gave the best control but was toxic to shortleaf pine seedlings at all levels tested (table 9-1). Bordeaux mixture, Dichlone®, and Maneb® gave good control at one or more concentrations and were not phytotoxic. Dichlone and Maneb were more effective than Bordeaux mixture at low concentrations and were selected for further testing.

Pawuk (1983) reported that both Maneb and Dichlone reduced alga development (table 9-2). Alga control was better when fungicides were applied at both 3 and 8 weeks or once at 5 weeks than once at 3 weeks. There was an interaction between drench rate and fungicide. Maneb was better than Dichlone at 0.8 or 1.0 mg/cm^2 but not at 0.4 or 0.6 mg/cm^2. At each drench schedule, alga development decreased as Maneb concentration increased. This trend was not present in the Dichlone treatments.

Drenching increased height growth over the control treatment. Seedlings drenched with Maneb were significantly taller than those drenched with Dichlone, but they differed by only 0.7 cm. Height growth was unaffected by drench schedule but was affected by drench rate. Seedlings from the 0.4 mg/cm^2 treatment were smaller than those from the 0.8 or 1.0 mg/cm^2 treatment. None of the other treatments differed from each other.

Drench schedule or rate did not affect seedling dry weight, although all treatments resulted in heavier seedlings than the control. Seedlings drenched with Maneb were larger than seedlings drenched with Dichlone.

Neither Maneb nor Dichlone inhibited the growth of shortleaf pine seedlings, and growth was greater in many treatments, especially Maneb, than in the control. Maneb and Dichlone may have protected the seedlings from pathogenic soil fungi.

9.4 Pest Control

The location of the greenhouse facility may affect the type and severity of pest problems. For example, infestations of pales weevils may occur when the facility is near a mill complex.

9.4.1 *Weeds*—Where sterile growing media are used and tree seed is weed free, weeds in the containers are not a problem. Weed seeds can be drawn into the greenhouse through the ventilation system or carried in on workers' feet. This can be minimized by controlling weeds close to the greenhouse and through proper sanitation. The weed seeds introduced into the

Table 9-1.—*Alga control on potting soil[1] treated with 11 chemical substances (adapted from Pawuk (1983)*

Treatment	Alga control[2]			
	0.02[3]	**0.03**	**0.04**	**0.05**
Simazine®	0.8	0.0	0.0	0.0
	0.1	**0.2**	**0.3**	**0.4**
Dichlone®	1.8	1.2	0.8	0.5
Maneb®	2.8	1.2	0.8	0.2
Bordeaux mixture	4.0	3.0	2.0	0.8
Captan®	2.5	3.2	3.2	2.8
Sulfur	3.0	3.2	3.5	3.8
Zineb®	3.5	4.0	3.8	3.8
Copper sulfate	4.0	4.0	3.8	3.8
Kocide 101®	4.0	4.0	4.0	4.0
	0.5	**1.0**	**1.5**	**2.0**
Cutrine®	2.5	3.5	2.0	1.8
Clorox®	3.2	3.0	2.5	3.2
Untreated control		3.9		

[1] Potting medium consisted of peat/vermiculite (1:1) in Styroblock-2® containers.

[2] Alga control categories (measured at 10 weeks): 0 = no algae present, 1 = algae present but barely detectable, 2 = algae forming a pale thin film, 3 = algae forming a thin mat less than 0.5 mm thick, 4 = algae forming a thick mat greater than 0.5 mm.

[3] Numerals in bold type face are amount of chemical applied per surface area (mg/cm^2).

Table 9-2.—*Alga development and shortleaf pine seedling growth in containers drenched with Maneb and Dichlone (adapted from Pawuk 1983)*

Variables	Alga[1] rating	Seedling	
		Height	Dry weight
		cm	*mg*
Material			
Control	2.7	14.5 c	412 c
Maneb	1.5	16.7 a	528 a
Dichlone	1.9	16.0 b	474 b
Time applied			
Week 3 and 8	1.6 b[3]	16.4 a	505 a
Week 3 only	1.8 a	16.4 a	512 a
Week 5 only	1.7 b	16.2 a	486 a
Drench rate (mg/cm^2)[2]			
0.4	2.0	15.8 b	489 a
0.6	1.7	16.4 ab	502 a
0.8	1.6	16.7 a	508 a
1.0	1.5	16.6 a	505 a

[1] Alga control 0 = no algae present, 1 = algae present but barely detectable, 2 = algae forming a pale green film, 3 = algae forming a thin mat less than 0.5 mm thick, and 4 = algae forming a thick mat greater than 0.5 mm thick.

[2] An interaction among drench rates and materials occurred in the alga development data. Maneb was better than Dichlone at the 0.8 or 1.0 mg rates but not at the others.

[3] Mean separation in columns for treatment variable groupings by Duncan's Multiple Range Test, 0.05 level.

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greenhouse will germinate in the containers or on the floor. Those that germinate and grow in the containers can be removed by hand. Greenhouses with gravel floors can develop a considerable growth of weeds on the floor. This is not only unsightly but also unsanitary. These weeds may harbor other pests. Because the weeds develop between and under benches, they may be hard to control manually. The gravel floors of greenhouses can be treated with non-volatile broad spectrum herbicides such as simazine. Apply them so that the tree seedlings are not contaminated.

9.4.2 *Rodents*—Exclusion of rodents from the greenhouse is important. The principal pests are mice, which can eat or cache large numbers of seeds from containers in a short time. They will also clip young succulent seedlings. The main defenses are construction of physical barriers, minimizing rodent cover near the greenhouse, and trapping or baiting. Areas around the greenhouse should be clean and free of debris or plants that will shelter or provide food for rodents. The greenhouse should be tightly constructed at the base, and all doors should automatically close when released. Elimination of any habitat for mice, combined with barriers to greenhouse entry, will usually prevent serious rodent problems. Some limited trapping or baiting may be necessary, however. Warfarin® as treated oat bait is the most commonly used rodenticide at present (Tinus and McDonald 1979).

9.4.3 *Insects*—Most common insect pests, such as ants and caterpillars, are not serious pests in seedling culture. They can usually be controlled by sanitation, barriers, and baiting. Serious insect pests usually enter the greenhouse through the ventilation system. Under greenhouse conditions, these insects can reproduce rapidly and cause extensive damage. The most bothersome are aphids, whiteflies, scales, thrips, and mites. Large insects occur less frequently. They are more obvious, and are easier to identify and control.

If harmful insects are present, eradicate them with approved insecticides. In most cases, some limited use of chemical controls is needed despite the most careful avoidance measures. If management is alert and observant, the see-and-treat program should be best. The mode of application and chemical used should be designed for the target insect. Timing the application is also very important to achieve optimum effectiveness. Some approved insecticides are listed for the common insect problems in table 9-3.

9.5 Control of pH and Salts

The availability of minerals to the plant is affected by many factors. Two important ones are hydrogen ion concentration (expressed as pH level) and the cation exchange capacity of the medium. The effect of pH on nutrient element availability is shown in fig. 9-7. The optimum growth for most conifer seedlings occurs in the range of 5.0 to 6.0 (Kramer and Kozlowski 1960). In predominantly organic media, optimum pH may be somewhat more acid than with less organic soils (Lucas and Davis 1961). At increasing pH levels above 5.5, availability of phosphorus and manganese drop rapidly (fig. 9-7).

Limited data indicate that pH ranges within those normally encountered have little adverse effect on germination (table 9-4). Only at an extremely high pH is germination reduced, and then only on an inert medium. The peat medium buffered the high alkaline effects, and germination was less affected.

9.5.1 *Measurement of pH*—The pH is conveniently measured at two places: in the water applied and in

Table 9-3.—*Insecticides for greenhouse pests (adapted from Tinus and McDonald 1979)*

Type of insect	Chemicals for control	Remarks
Thrips	malathion, dieldrin, lindane, parathion, Sulfotepp®	Apply malathion and lindane frequently
White flies	pyrethrum, rotenone, nicotine sulphate, malathion	pyrethrum, rotenone and nicotine sulphate control nymphal stage
Scales	malathion, nicotine sulphate and soap	
Aphids	nicotine sulphate and soap, lindane, malathion, Sulfotepp, parathion, Thiodan	nicotine sulphate on warm days only; do not apply parathion before or after sulfur
Mites	sulfur, Aramite®, Dimite®, Kelthane®, Ovex®, malathion	

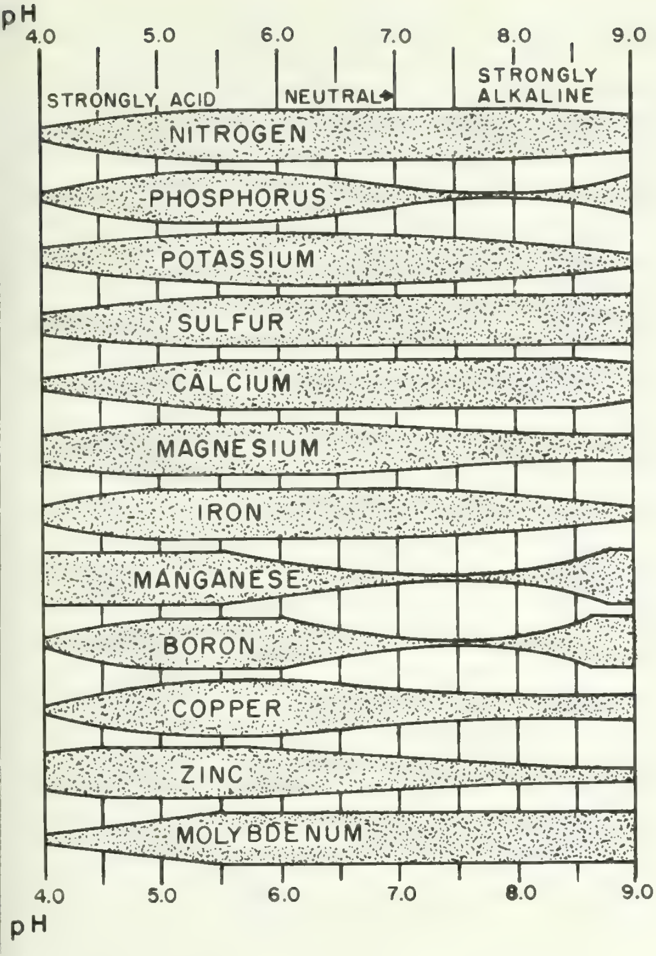

Figure 9-7.—*Influence of pH on availability of plant nutrients in organic soils—widest part of bar indicates maximum availability (adapted from Lucas and Davis 1961).*

the leachate from the bottom of the container. To provide an adequate supply of water to the trees and prevent salt accumulation in the containers, container tree seedlings should be watered enough to insure that water flows through the container during each irrigation. The method for monitoring pH suggested by Tinus and McDonald (1979) consists of:

1. Measuring pH of the nutrient solution applied.
2. Measuring pH of the "leachate" (water that runs through the growing medium and out the bottom of the container).
3. Comparing the two readings to make inferences about the pH of the soil solution in the growing medium at time of reading and as a trend over time.

This method avoids the usual method of soil pH determination, where dry soil is mixed with water in some standard proportion, allowing the mixture to stand for about one-half hour; then, while the mixture is stirred, potentiometer electrodes are inserted, and the pH is measured on the soil suspension (Jackson 1958). The standard procedure is difficult to use in tree seedling operations because of the small container volumes.

The difficulty of catching leachate from containers varies with the type of container. It is essential that the fluid caught has passed through the medium in the container. Several container systems are designed so that irrigation water can reach the bottom of the bench, via cracks, dividers, holes, etc., without going through the container. This "bypass" water must not enter the sample being collected for pH measurement. In most cases a minimum of 3 to 5 ml of leachate is required to take a pH reading; it is better if you can obtain more than this amount. The sample size should be standardized. The pH of the first leachate coming from the container will be different from that coming later, since it may contain more salts. This is not important as long as the same volume of fluid is caught at each collection.

9.5.2 *Adjusting pH with Irrigation Water*—The pH of the media is best controlled by the ingredients used and how they are blended. The potting mix should initially be acidic. Depending upon the nature of the potting mix (see section 6.2), it may be desirable to irrigate with acidified water to maintain low pH. Matkin and Peterson (1971) describe the techniques necessary to lower the pH with acid. Phosphoric acid is the least dangerous acid to use for this purpose. Considering the high value of the crop and the crucial nature of pH control to plant nutrition and disease control, nurserymen should monitor the pH of the growing medium and make adjustments as needed.

9.5.3 *Measurement of Salt Concentrations*—Some water sources have high levels of dissolved salts; these can cause injury to plants in four ways (Fuller and Halderman 1975): (1) reduce moisture availability, (2) decrease soil permeability, (3) cause direct toxicity, and (4) alter nutrient availability. The best control for saline water problems is to avoid them in the first place by a comprehensive examination of water quality. However, because of the large amount of irrigation water used in most greenhouses, there is a real potential for salt accumulation in the potting media, not only from salts in the water source but also in the fertilizers.

Table 9-4.—*Average germination of slash pine seeds as affected by pH*

	Germination media	
pH	Peat-vermiculite	Kimpak® cellulose
	percent	
4	93	90
7	90	89
10	91	90
13	90	75
Mean	91	86

Salt concentrations are measured by use of an electrical conductivity (EC) meter to monitor the irrigation solution and the leachate. Very pure irrigation water may have EC's as low as 100 to 200 μmhos. Water, carrying a complete nutrient solution and buffered for conifer growth, will range from 500 to 1,000 μmhos higher than the untreated water, normally in the 1,500 to 2,000 μmhos range (Tinus and McDonald 1979).

High salt concentrations generally result in stunting, although seedlings may also be chlorotic. If the leachate EC exceeds the nutrient solution EC by 1,000 μmhos or more, the nursery should immediately take steps to rectify the problem. Normally, the two should be within 100 to 200 μmhos. If the EC of the leachate is 3,000 μmhos or more, the trees are probably dead or dying. Normally, total nutrient solutions should not be used if the EC of the irrigation formulation exceeds 2,200 to 2,400 μmhos. This should be a problem only in the western extremes of the southern pine range.

A rise in the normal EC of the leachate without a similar rise in the EC of the irrigation solution applied indicates there is not enough leaching of the growing medium (i.e., not enough water being applied per irrigation cycle). The best solution to excess salt buildup is to ensure that the excess salt is leached from the potting mix during each irrigation by watering until leachate drains from the bottom of the container.

9.6 Seedling Nutrition

Information about the nutritional needs of southern pine seedlings is very limited. Fortunately the range of nutrient concentrations that will provide good growth is quite broad, and most coniferous tree species are similar in their requirements. Nutrients needed in relatively large amounts are termed macronutrients. Not only are the total amounts of macronutrients important, but the relative proportions of each element are important for proper nutrition. Micronutrients are also important but are only needed in trace amounts for seedling growth.

The six macronutrients—nitrogen, phosphorus, potassium, calcium, magnesium, and sulfur—have been studied in some detail, and recommendations are available. The recommended nutrient levels for bareroot southern pine nursery soils are: phosphorus, 25 to 38 ppm; potassium, 75 to 100 ppm; and calcium, 300 to 600 ppm (Stienbeck and others 1966). In another study the best growth of slash pine in sand culture was obtained when nitrogen and potassium were both greater than 125 ppm but less than 625 ppm (McGee 1963). From literature on other conifers, magnesium should be in the range of 15 to 73 ppm, and sulfur in the range of 20 to 150 ppm (Tinus and McDonald 1979).

Although micronutrients are needed in very small quantities, they are critical, and if they are not present in sufficient amounts they can limit growth. The micronutrients include: iron, boron, manganese, chlorine, zinc, copper and molybdenum. Work with these elements has been extremely limited. Recommendations for Scots pine (*Pinus sylvestris* L.) and Norway spruce (*Picea abies* (L.) Karst) are: iron, 0.93 ppm; boron, 0.17 ppm; manganese 0.17 ppm; zinc, 0.02 ppm; copper, 0.02 ppm; and molybdenum, 0.003 ppm (Ingestad 1962). The recommendations for macronutrients and micronutrients are summarized in table 9-5.

Ratios among the macronutrients are also important if the nutrients are to be readily available for plant growth. For the first several weeks, the nitrogen to phosphorus ratio should be greater than or equal to 1, and the phosphorus to potassium ratio should be less than 1 (Brix and van den Driessche 1974). Late in the growing season the proportion of nitrogen can be reduced.

Deficiencies or imbalances of nutrients will result in slow growth and poor seedling quality. Mineral deficiencies are often expressed as patterns of unusual leaf coloration. A summary of deficiencies is listed in table 9-6. A dichotomous key to mineral deficiency symptoms in loblolly pine seedlings using Munsell color charts has been developed by Lyle (1969).

However, if mineral nutrient deficiency symptoms appear, the crop is already affected. Production time will be lost while the crop recovers and field performance may be permanently impaired. For a successful and profitable crop, deficiencies must be avoided.

9.6.1 *Incorporation with Growing Medium*—Incorporating slow release fertilizers into the growing medium or adding granular fertilizer as a "top dressing" to the containers is a common practice in horticulture. The use of these techniques in seedling oper-

Table 9-5.—*Recommended nutrient concentrations for southern pines*[1]

Nutrient	Concentration
	ppm
Nitrogen	125–625
Phosphorous	25–38
Potassium	75–625
Calcium	300–600
Magnesium	15–73
Sulfur	20–150
Iron	0.93
Boron	0.17
Manganese	0.17
Zinc	0.02
Copper	0.02
Molybdenum	0.003

[1] These recommended nutrient concentrations should not be considered optimum but can be used as a basis for fertilization until more complete information is available.

Table 9-6.—*Visual deficiency symptoms in conifers (adapted from Morrison 1974)*

Deficient nutrient	Symptoms
Nitrogen	General chlorosis and stunting of needles increasing with severity of deficiency; in most severe cases needles short, stiff, yellow-green to yellow; in some cases purple tipping followed by necrosis of needles at end of growing season.
Phosphorus	Youngest needles green or yellow green; older needles distinctly purple-tinged; purple deepens with severity of deficiency; all needles purple in very severe cases in seedlings.
Potassium	Symptoms vary; usually needles short, chlorotic, with some green near base and, in some severe cases, purpling and necrosis with top dieback or little or no chlorosis; purpling, browning or necrosis of needles evident wherever they are found on the tree.
Calcium	General chlorosis followed by necrosis of needles, especially at branch tips; in severe cases, death of terminal bud and top dieback; resin exudation.
Magnesium	Yellow tipping of current needles followed in severe cases by tip necrosis.
Sulfur	General chlorosis of foliage followed in severe cases by necrosis.
Iron	More or less diffuse chlorosis confined in milder cases to new needles; in more severe cases bright yellow discoloration with no bud development.
Manganese	Needles slightly chlorotic; in severe cases some necrosis of needles.
Boron	Tip dieback late in growing season with associated chlorotic-to-necrotic foliage, intergrading to dieback of leading shoot with characteristic crooking.
Zinc	Extreme stunting of trees with shortening of branches; needles yellow, short, crowded together on twig, sometimes bronze tipped; older needles shed early, with resultant tufting of foliage; in severe cases trees rosetted with top dieback.
Copper	Needles twisted spirally, yellowed or bronzed; "tipburn" or necrosis of needle tips evident; in severe cases young shoots twisted or bent.
Molybdenum	Chlorosis of leaves followed by necrosis of tissue, beginning at tip and eventually covering whole leaf.

ations has been limited. The most prevalent method has been the incorporation of Osmocote® formulations. Although good growth may result when using the Osmocote 18-6-12 formulation with southern pines, such incorporation may result in overfertilization and limit the ability of the grower to stop height growth and harden the seedlings when desired. An exception may be when a spring outplanting is anticipated and the need for hardening is not as great. However, the incorporation of nutrients still limits the options of the grower, both in nutritional balances available and manipulation of seedling quality.

9.6.2 *Soluble Commercial Mixes*—Most tree seedling growing operations use soluble commercial fertilizers. These are dissolved in water and injected into the irrigation system of the greenhouse or sprayed over the trees by hand equipment. These fertilizers are formulated by a number of manufacturers and are available in numerous types, formulations, and proportions of macronutrients and micronutrients.

Experiences using soluble fertilizer compounds for growing different species of trees in different locations, containers, and potting mixes has increased in the last few years. Nurserymen considering the use of commercially prepared soluble formulations should consult with other nurserymen to determine which materials to use and the best times of applications. Peters® Peat-lite Special formulations work well with southern pine grown in peat-vermiculite media. However, it is not wise to assume that what works well in one situation will necessarily work well in another. This is because the fertilizer interacts with the water composition of a specific site, the potting media, the species grown, and the growing conditions peculiar to each greenhouse (Tinus and McDonald 1979). Some fertilization manufacturers offer custom fertilizer formulation based on their analysis of water samples and crop needs.

Although commercially formulated soluble chemical fertilizers are convenient to buy and use, they have some drawbacks (Tinus and McDonald 1979):

1. The manufacturer controls the precision of the formulation.
2. The user is limited to the proportions of the nutrients available in mixes.
3. The user often has limited information on what chemical compounds are used to supply the nutrient ions and therefore the cause of any problem may be hard to identify.
4. The nurseryman cannot adjust the nutrient mix to take advantage of nutrients in the water supply or to adjust the pH of the solution by varying the salts used in the formulation.

However, soluble commercially prepared fertilizers are used very successfully in container operations. They are also very convenient and easy to use when applied through the irrigation water.

9.6.3 *Local Nutrient Formulations*—Another method of fertilizing tree seedlings is with locally mixed nutrient stock solutions. These are formulated by adding various amount of technical grade chemical components to water according to the optimum nutrient regime for the species, the potting mix, and water composition. Tinus and McDonald (1979) give an excellent format for determining the chemical composition best suited to an individual nursery situation.

Local mixed formulations are more difficult to handle than commercial mixes, and optimum nutrient concentrations are not clearly specified for most species. In such cases, the local formulation may do no better than a commercial mix.

9.6.4 *Timing of Initial Application*—During germination, the seed megagametophyte (endosperm) supplies sufficient phosphorus and other essential nutrients, so that additional fertilization is unnecessary. The newly germinated seedling reportedly takes up few elements other than carbon, hydrogen, and oxygen until 10 to 14 days after germination (Carlson 1979). Brix and van den Driessche (1974) have reported, however, that growth of container seedlings could be helped with the incorporation of slow-release nutrients into the potting media during the first few weeks of germination. Generally, the addition of mineral nutrients during germination is not recommended, because they are supplied by the seed and they may increase losses due to damping-off fungi (Tinus and McDonald 1979). Fertilization is usually scheduled to begin after the seed coats have been shed from the cotyledons. This delay can have considerable effect on seedling development. Delaying initial application of nutrients until drop of the seed coats (about 3 weeks) can reduce loblolly pine seedling development by nearly 20 percent (fig. 9-8). If the crop is on a short rotation, fertilization at the time of seeding may be desirable. It may be that, although the germinants can not effectively utilize the nutrients at this early stage of development, availability at the earliest possible time will hasten growth. If a short growing period is not critical, delay until germination occurs may be beneficial from a disease management viewpoint.

9.7 Mycorrhizal Inoculation

Mycorrhizae are the structures resulting from the colonization of a tree host root by a suitable fungus. The value of mycorrhizae to tree growth has been known to foresters for decades. They increase availability and absorption of nutrients, especially phosphorus, the most limiting nutrient on most pine sites in the South. Ectomycorrhizae also protect fine absorbing roots from pathogen attack (Marx 1972).

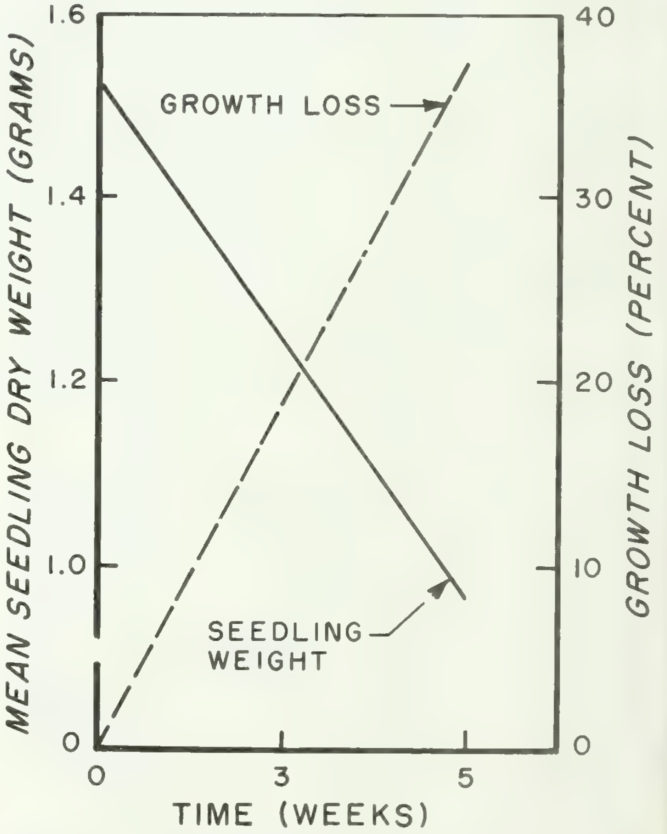

Figure 9-8.—*Effects of timing of initial fertilizer applications on dry weights of loblolly pine seedlings grown for 20 weeks. Time is the delay in application of fertilizer.*

Under natural conditions, pines will not survive or grow well without mycorrhizae. Ample evidence exists to document the benefits of having visible mycorrhizae on the root systems of nursery-grown seedlings when they are outplanted in the field (Marx and Artman 1979).

Seedlings can, however, be grown quite satisfactorily without mycorrhizae if adequate nutrients are provided and pathogens are controlled. Normally, containerized seedlings are grown under conditions that tend to optimize growth, i.e., high levels of fertility. These conditions normally limit the development of mycorrhizae (Marx and Barnett 1974, Marx and others 1977), and lower fertility regimes may be necessary to allow development of mycorrhizal inoculum.

When greenhouses are located near forested areas where airborne mycorrhizal spores are abundant, inoculation may not be necessary. Barnett (1982) found that *Thelephora* developed on seedling root systems in containers from airborne spores in amounts negatively related to the amount of inoculated *Pisolithus* present. High fertility did not seem to inhibit this *Thelephora* development. Further evaluations of the relationships among mycorrhizal presence and seedling size with field performance of shortleaf and longleaf seedlings indicated that initial seedling size was more related to growth than amounts of mycorrhizae on the root systems (Barnett 1982). This relationship makes it very important to consider the effect of differences in seedling size at the time of outplanting on field performance.

Under the humid conditions typical of the Southeast, seedlings grown in greenhouses normally become inoculated with mycorrhizae by windborne inoculation. If so, the effort and cost to inoculate them is probably not necessary for seedling regeneration throughout much of the region. Even if the seedlings lack mycorrhizae when they are outplanted in the field, they usually become inoculated quickly because of the presence of the fungi at the site. However, there is considerable evidence that inoculation with mycorrhizae improves seedling performance on difficult sites such as arid soils, reclamation areas, and shelterbelt plantings in the Great Plains where inoculum may be scarce or lacking.

If inoculation with mycorrhizae is thought desirable or necessary, one method available is to incorporate 2 to 3 percent by volume of forest duff into the potting mix (Tinus and McDonald 1979). The duff should be collected from under a stand of trees of the same or closely related species. Rake aside the undecomposed litter and scoop the humus with a flat shovel. Screen out particles too large to mix well with the rest of the medium. Keep the inoculum moist until used.

Although duff inoculum will work well (Goodwin 1976), it may add harmful organisms. Some research has indicated that it may actually lower survival and growth (table 9-7). McGilvray[1] reported that the addition of duff reduced initial seedling survival by 7 percentage points. The risk of using duff can be assessed by collecting some inoculum well in advance and filling a few containers. Then grow seedlings for several months and evaluate detrimental effects before it is used on a large scale (Tinus and McDonald 1979). Use a pure culture of the desired mycorrhizal fungus if possible.

9.7.1 *Vegetative Mycelia*—Marx and his coworkers (Marx and Bryan 1975, Marx and Rowan 1981) have developed techniques to produce mycelial inocula of *Pisolithus tinctorius* (Pt) and *Thelephora terrestris* (Tt) in a peatmoss-vermiculite culture. These techniques have made it feasible to propagate and manipulate these fungal symbionts for research purposes. In order for mycorrhizal manipulation to become common practice, larger quantities of high-quality inoculum must be available.

9.7.2 *Basidiospores*—A simple and less expensive means of inoculation with Pt is through the use of basidiospores. Basidiospores are the primary agents for disseminating many ectomycorrhizal fungi. Several workers have used spores of specific fungi as inoculum for synthesis of mycorrhizae on pine (Marx and Ross 1970, Theodorou 1971). *Pisolithus tinctorius* produces large basidiocarps or puff balls that contain many spores. Marx and Bryan (1975) collected over 1,300 grams of spores of this fungus under mature pine in less than 3 hours on a strip-mined coal spoil in northwest Alabama. One gram contained approximately 1.1 billion spores. Unfortunately, viability of the spores is difficult to determine (Lamb and Richards 1974). It appears that the best way to determine spore viability is in actual mycorrhizal synthesis tests or operational use.

The most successful method of inoculating media with spores of Pt has been by mixing dry spores with the peat-vermiculite medium before containers are filled. The addition of spores suspended in water to the medium is less effective (Marx 1976). The use of about 3 grams of spores per cubic foot of potting mix has been effective.

Another technique that shows promise is to coat or "pelletize" pine seeds with spores of Pt. Theodorou (1971) found that coating seeds of Monterrey pine (*P. radiata* D. Don) with freshly harvested basidiospores was an easy and effective way to introduce mycor-

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[1] McGilvray, J.M. 1973. Evaluation of mycorrhizal formation and its importance in the survival and growth of containerized loblolly pine seedlings. U.S. Forest Serv., Southern Forest Exp. Sta. Establishment and Final Report SO-1102-9.17, 11 p., Pineville, LA 71360 (unpublished).

Table 9-7.—*Percent survival and height of loblolly pine seedlings grown with and without mycorrhizal duff in two growing media*

Media	Treatment	Survival At 3 months	Survival At 8 months	Average height at 8 months
		percent	*percent*	*cm*
Peat-vermiculite mix	Decomposed litter	86 a[1]	85 a	12.5 c
	Control	90 b	89 a	11.0 b
Sand-soil-peat mix	Decomposed litter	84 a	83 a	8.5 a
	Control	94 b	88 a	8.8 a

[1] Averages followed by the same letter do not differ significantly at the 0.05 level.

rhizal fungi into soils. International Forest Seed Company of Birmingham, Alabama, has a commercial process to pellet southern pine seeds with Pt spores. After seeding with pelletized seeds, the container should be drenched with water to insure the pellet is washed from the seed coat. Otherwise, the pellet may inhibit germination. Perhaps the greatest problem in the use of spores as a method of mycorrhizal inoculation is the lack of a technique to evaluate spore viability.

9.7.3 *Cultural Modifications*—Inoculation of the container growing media with mycorrhizal inoculum necessitates some modification of the normal cultural regime if development on the pine root system is expected. The high fertility levels that are usually used to optmize seedling growth should be reduced by about one-half, or development of mycorrhizae will be limited (Marx and Barnett 1974, Marx and others 1977).

Other cultural techniques may also affect mycorrhizae. The use of fungicides can have either a deleterious or a beneficial effect on mycorrhizal development. Pawuk and others (1980) evaluated the effects of seven fungicidal drenches on Pt and Tt mycorrhizal development of longleaf pine grown in containers (see section 9.2.2.). The degree of mycorrhizal development differed significantly among fungicide treatments (table 9-8). Only seedlings drenched with Banrot and Benlate had greater development than the control.

Since Benlate is one of the most effective fungicides for controlling *Fusarium*, an additional study was initiated to test the effect of Benlate in stimulating mycorrhizal development on shortleaf pine in a peat-vermiculite medium and to identify effective drench rates and schedules (Pawuk and Barnett 1981). Seedlings were drenched (2.5, 5, and 10 mg in 15 ml of water per individual) prior to sowing and at either 2-, 4-, or 8-week intervals over an 18-week period. Seedlings drenched with high rates of Benlate and seedlings receiving frequent drenchings generally formed the most mycorrhizae (table 9-9). However, a dosage rate frequency interaction was present (table 9-10).

During the study, seedlings received 5, 10, 20, 40, or 80 mg benomyl, depending on drench schedule and dosage rate. With one exception, mycorrhizal development increased with increased amounts of Benlate.

Benlate application also increased seedling diameter, height, and weight (table 9-9). Highest Benlate dosages produced the largest seedlings. The growth response is probably due to control of soil fungi that reduce seedling growth or to effect of increased mycorrhizal development on Benlate-treated seedlings.

9.8 Control of Root Morphology

Growing seedlings in containers dictates that root morphology will be different than when grown in the wild. Early results with containerized seedlings showed the desirability of restricting root egress from the container during the greenhouse culture period. Copper paint (Saul 1968) or screening (Barnett and McGilvray 1974) was found to inhibit root growth from the bottom of containers and resulted in increased survival of seedlings. However, air pruning was found to be a more efficient means of eliminating root growth from containers. The key to effective air pruning of roots is to provide for easy air access around the container openings.

There is considerable concern about the relationship of the root pattern caused by the container and subsequent field performance and stability of seedlings and young trees (see section 5.4). The type of container used will, of course, have considerable impact on root configuration. Containers are now designed with vertical ribs, rounded horizontal corners, and egress holes with adequate ventilation beneath them for air pruning. These features keep the roots within the container and produce a more or less parallel vertical root system with little root spiraling (Hiatt and Tinus 1974).

Table 9-8.—*Effect of fungicide treatment on development of ectomycorrhizae on longleaf pine seedlings grown in* Pisolithus tinctorius *infested and noninfested media (from Pawuk and others 1980)*

	Pisolithus infection		Airborne symbiont infection	
Fungicide	Infested	Noninfested	Infested	Noninfested
Banrot	26.21 a[2]	0.00	4.95 b	5.23 b
Benlate	25.00 ab	0.00	6.16 b	13.55 a
Mertect	19.97 bc	0.00	5.66 b	11.84 a
Truban	14.59 d	0.00	4.61 b	1.77 c
Dexon	10.65 e	0.00	10.07 a	11.03 a
Captan	6.80 e	0.00	4.71 b	7.38 b
Terraclor	0.00 f	0.00	1.98 c	0.88 c
Control	17.53 cd	0.00	6.27 b	7.66 b

[1] Values are expressed as a percentage of short roots forming ectomycorrhizae.

[2] Means followed by similar letters are not significantly different at the 0.05 level.

Table 9-9.—*Mycorrhizal development by* Pisolithus tinctorius *and growth of shortleaf pine seedlings drenched with Benlate (main effects table) (from Pawuk and Barnett 1981)*

Benomyl[1]		Shortleaf pine Diameter	Height	Dry weight
Dosage mg/seedling	*Percent infection*	*mm*	*cm*	*mg*
2.5	17.67[2]	2.06a[3]	13.54a	462b
5.0	24.00	2.04a	13.26a	478b
10.0	36.67	2.12a	13.80a	508a
Frequency				
every 2 wks	34.33[4]	2.19a	14.44a	531a
every 4 wks	27.00	2.06b	13.92a	482b
every 8 wks	17.00	1.96b	12.24b	435c
Control	8.00	1.94	11.90	408

[1] The dosage X frequency interaction was significant. See table 9-10 for mean separation.

[2] Values represent the mean of the three frequencies of application.

[3] Means with dosage rates and frequencies followed by the same letter within columns are not significantly different at the 0.05 level.

[4] Values represent the mean of the three dosages of benomyl.

Table 9-10.—*Mycorrhizal development by* Pisolithus tinctorius *as affected by Benlate dosage and drench frequency (interaction table) (from Pawuk and Barnett 1981)*

	Benlate dosage (mg/seedling)		
Drench frequency[1]	2.5	5.0	10.0
	-------- *percent infection* --------		
Every 2 weeks	25 c[2]	24 c	54 a
Every 4 weeks	16 c	31 b	34 b
Every 8 weeks	12 e	17 d	22 c

[1] For an 18-week period.

[2] Means followed by the same letter are not significantly different at the 0.05 level.

Root spiraling has been the most prevalent problem of root configuration imposed upon southern pines by containers, and proper container selection will largely eliminate this problem. Although a vertically oriented root system is common in plug-type containers, the rapid root growth from the lower portion of the plug does not seem to result in root deformity. In fact, it probably results in improved seedling survival and growth on adverse sites (Barnett 1982). However, the early development of roots from the bottom of the plugs may result in less rapid mycorrhizal development. The microenvironment and soil associates of these more vertically egressed roots are not as favorable as on lateral root development closer to the soil surface (Ruehle 1983).

There are techniques that may be used to change or control the pattern of root morphogensis in plug-type container systems. Burdett (1978) has reported that copper carbonate in acrylic latex paint applied to container walls will stop root growth at that wall. This was done by mixing a small amount of copper carbonate (30 to 100 g/l or 25 to 83 lb/100 gal) with acrylic latex paint and painting the inside of the container with the mixture before filling it with medium. When their tips reached the wall of the containers, many of the lateral roots of the seedlings stopped growing instead of turning and continuing to grow down the walls to the root egress hole. The laterals that stopped often developed a series of adventitious roots. These roots also stopped growth at wall contact. The result was a series of root tips at the container wall. Upon removal from the container, these root tips resumed growth outward from the sides of the root "plug." This lateral root growth promises better lateral anchorage and access to water and nutrients and suggests such root morphogenetic control could be a feasible operational procedure. McDonald and others (1981) also evaluated some synthetic auxin compounds that gave results similar to copper carbonate.

Although some research with these techniques is underway with southern pines, the results are still preliminary. It has been observed, however, that extraction from plugs becomes more difficult, since there are less roots on the plug surface to bind the medium together.

9.9 Carbon Dioxide Enrichment

There are about 325 ppm carbon dioxide (CO_2) in the atmosphere; this is the source of carbon for all green plants. When plants are exposed to conditions of good light and water, growth may be limited by atmospheric carbon dioxide (Kramer and Kozlowski 1960). Since CO_2 can be especially limiting in a closed greenhouse, many growers routinely add it to their greenhouse atmospheres (see section 8.2.4). Increases in seedling growth and dry weight of 50 to 100 percent can result from concentrations of 1,000 ppm CO_2 during daylight hours (Tinus 1972, Yeatman 1970); however, some species are not as responsive as others (Canham and McCavish 1981), and we do not know the effects of CO_2 enrichment on southern pines.

9.10 Acclimating Seedlings

When growing conditions are optimized for rapid height growth, succulent seedlings with a high shoot-to-root ratios generally result. For outplanting under highly favorable conditions, these may survive and grow well, but usually at least some control of top growth is needed. Excessively tall seedlings can be top pruned (see section 9.11), but cultural control of top growth is better.

Most seedlings will cease height growth and set bud when exposed to water stress and short photoperiods. Reducing the nitrogen provided to the seedlings also helps to slow growth. The ease at which growth is stopped depends on the season, but it can be stopped regardless of time of the year. The length of time allowed for the initial hardening stage depends on the environmental conditions expected at time of outplanting. Cessation of growth, followed by stem lignification and bud set, is the normal sequence during initial hardening.

9.10.1 *Managing Moisture Stress*—Total water potential is composed of soil water potential and plant water potential and refers to the status of water with relation to the soil, plant, and air. Soil water potential depends on moisture content and soil texture. Plant water potential depends on soil water potential and atmospheric evaporative demand. Evaporative demand rises with increasing air temperature and decreasing humidity. Radiation intensity and wind speed also contribute, but less directly. Water potential is measured in bars, and optimum soil or plant water potential is usually near 0 bars.

Plant moisture stress is the inverse of plant water potential; as moisture stress increases plant water potential decreases, becoming more negative. Likewise, soil tension is the inverse of soil water potential. Before dawn, soil water potential and plant water potential are in equilibrium, but not necessarily equivalent. While soil water potential declines as the soil dries, plant water potential fluctuates diurnally (fig. 9-9). As the day progresses, plant water potential drops until it stabilizes near midday, then slowly climbs during the afternoon and evening. At midday, the water potential of seedlings may be 7 to 10 bars below soil water potential. The wilting point of plants is defined as −15 bars, although mature trees are often well below that level at midday.

As discussed in section 9.1.1, water potential should be kept high while the seedlings are rapidly elongating. As seedlings approach the desired size, water potentials should be allowed to drop; this will bring about low-level moisture stress and begin the harden-

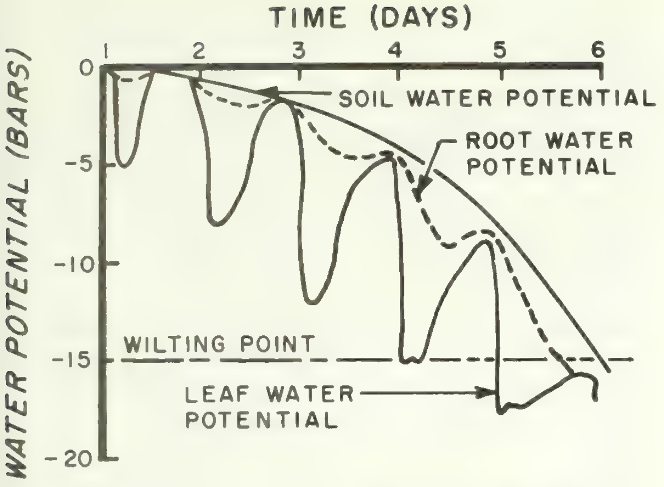


Figure 9-9.—*The influence of decreasing soil water potential on development of plant water stress (adapted from McDonald and Running 1979).*

ing process. In container nurseries, water potential can be evaluated indirectly by weighing the containers to determine moisture content, or by directly measuring plant water potential with a pressure chamber. Weighing is appropriate while the seedlings are small and water content is a major portion of the total weight. As the seedlings become larger, a pressure chamber is recommended to accurately assess plant water potential. When trying to optimize growth, the media should be kept at or near field capacity, or less than −0.3 bars (Tinus and McDonald 1979). Using the weighing method, this means the crop should be irrigated when sample containers dry to about 75 to 80 percent of their saturated weight (McDonald and Running 1979).

During the conditioning phase, midday plant water potential should be allowed to drop to between −12 and −15 bars to impair height growth and help initiate dormancy. The time required for plant water potential to drop to the desired level depends on moisture content of the media and evaporative demand. To maintain plant moisture stress at safe levels, careful monitoring of water potential is important. To aid in interpreting water potential readings obtained with a pressure chamber, McDonald and Running (1979) suggest graphing midday readings over a period of time and at different temperatures and humidities. The resulting curves relate available soil water to midday plant water potential for various levels of evaporative demand (fig. 9-10). Note that the curves are divided into segments by degree of moisture stress. Seedlings stressed beyond the wilting point (−15 bars) are in danger. In the range of −12 to −15 bars, seedlings undergo a conditioning stress. Above −12 bars, water potential does not limit seedling growth. Problems occur when interpreting midday water potentials along lines A-B and B-C. From A to B soil moisture is the same although plant water potential varies with different evaporative demands. From B to C plant water potential is constant despite different soil water contents, again because of different evaporative demands. The development of such curves will help to manage or to maintain water potentials at optimum or desired stress levels without endangering the crop.

9.10.2 *Nutritional Changes and Hardening*—In addition to stress, manipulation of nutrients is another means of increasing seedling hardiness. Once the seedlings have reached about 80 percent of the desired height (about 13 cm or 5.5 inches), reduce the application of nitrogen along with that of water. This aids in the reduction of stem growth. An increase in rates of phosphorus and potassium may help root growth and stem diameter growth to continue (Tinus and McDonald 1979). However, Timmis (1974) found that a rather extreme nitrogen-potassium imbalance strongly reduced the ability of containerized Douglas-fir seedlings to achieve cold hardiness. He found that the potassium-to-nitrogen ratio must be less than 1.0 to permit maximum cold hardening after an 11.5-week hardening regime. The frequency of nutrient applications should also be reduced.

9.10.3 *Cold Hardening*—Additional hardening beyond cessation of growth and stem lignification is needed if a late fall or winter outplanting is planned. This is done by gradually exposing seedlings to more severe conditions, primarily low temperatures, that will bring about physiological changes to enable the trees to tolerate the new conditions. Temperatures of 1 to 5 °C (34 to 41 °F) will generate considerable cold hardiness.

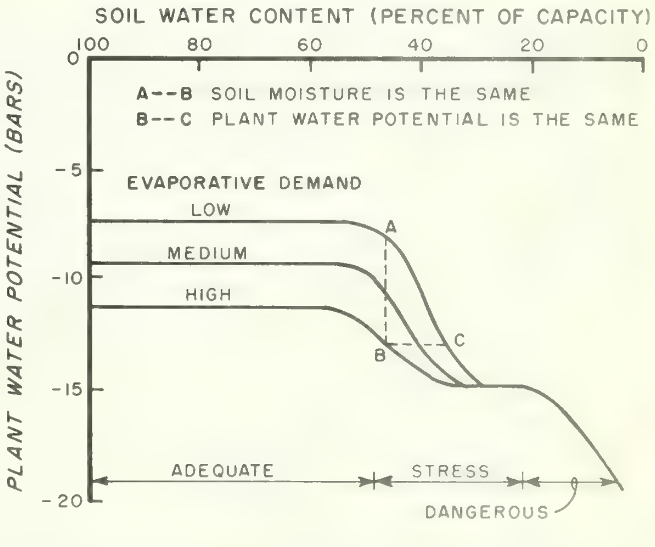


Figure 9-10.—*The change in midday plant water potential produced by changing soil water content and different levels of evaporated demand (adapted from McDonald and Running 1979).*

Mexal and others (1979) found that approximately 42 days of hardening are required to induce sufficient cold hardiness to enable loblolly pine seedlings to survive late fall and early winter outplanting. To ensure sufficient hardening, the hardening process should be initiated by mid-September so that outplanting may occur in November. When soil moisture is adequate, partially hardened stock may be planted successfully in September or October. Hardening can be accomplished by either exposure to low temperatures or to short photoperiods, but the exposure to low ambient temperatures is the most feasible technique.

Loblolly pine has a chilling requirement that must be satisfied before normal bud break and shoot elongation can occur. Garber and Mexal (1980) report that about 7 weeks of exposure to natural conditions during November and December are needed to satisfy the chilling requirement of nursery-grown loblolly pine seedlings. It is not known if small containerized seedlings that have not formed a terminal bud have a chilling requirement (Mexal and Carlson 1982). There are also probably seed source differences in the amount of chilling required. More northern sources are likely to have longer chilling requirements than more southern sources. There is insufficient information available now to evaluate the importance of chilling requirements in the culture of containerized southern pines.

9.10.4 *Cold Injury*—There is considerable variation among species in their susceptibility to cold injury. Loblolly and shortleaf pines extend into the northern portions of the southern states and are adapted to colder temperatures than slash and longleaf pine. Seeds of loblolly and shortleaf are stratified naturally as they overwinter on the soil surface; the seeds then germinate in the spring. The small seedlings are not well adapted to cold temperatures and are susceptible to subfreezing conditions. In constrast, longleaf pine is a more southern species and its seeds normally germinate in the fall soon after release from the cones. Recently germinated longleaf seedlings are then more resistant to cold injury than loblolly or shortleaf pine. Normally, longleaf seedlings survive the ambient temperatures that occur in their range during the fall and winter.

Slash pine is intermediate between longleaf and loblolly in susceptibility to cold. A portion of slash seeds normally germinate in the fall, while another portion overwinters and germinates in the spring. Tests indicate that slash seedlings are more cold resistant than loblolly pine (Barnett and McGilvray 1981).

9.11 Top Pruning

Top pruning of bare-root conifer nursery seedlings is used to retard excessive top growth and keep the seedlings in a better shoot-to-root balance. Normally, the tops are pruned while new growth is expanding and sufficient time is available for subsequent bud formation and normal development (Stoeckler and Jones 1957).

Clipping the needles of longleaf seedlings has been recommended for planting on adverse sites (Allen 1955). However, Derr (1963) reported some growth retardation resulting from clipping longleaf, and Langdon (1955) found no advantage to clipping South Florida slash pine needles (*Pinus elliottii* var. *densa* Little and Dorman).

The purpose of most of the pruning and clipping of conifers has been to reduce transpiration and thus improve seedling survival under adverse conditions. Results from a number of studies show no conclusive advantage for this technique. Photosynthetic production, which is necessary for root development, may be sufficiently reduced by pruning and clipping to account for variation in the results.

Top pruning of container-grown seedlings is normally not necessary. However, there are instances when seedling development has not been adequately controlled by cultural regimes, and then it may be desirable to prune in order to obtain a better seedling balance. It may be beneficial to clip the needles of longleaf pine because even at a low density, needle development in containers can be so great as to cause shading problems in these very intolerant seedlings. Clipping could be used, then, to allow uniform light exposure to all seedlings.

Evaluations of needle clipping or top pruning showed a reduction in initial seedling size and weight (table 9-11). No improvement in field performance resulted from clipping longleaf needles, but if clipped, those that were clipped early performed best. Loblolly and slash pine seedlings should be pruned early, if pruned at all. There was no marked improvement in field survival or growth that resulted from pruning. In fact, field growth was closely correlated with seedling size at time of outplanting. Correlation coefficients of 0.967, 0.956, and 0.923 resulted from comparisons of initial size and growth in the field after 2 years for longleaf, loblolly, and slash pine, respectively (Barnett 1985). Hence, the larger seedlings performed as good or better than those pruned.

10. DEVELOPMENT OF GROWING SCHEDULES

A plan should be developed to insure maximum utilization of greenhouse and shadehouse space consistent with the overall objectives of the greenhouse manager. It is useful to keep a written record of the planned crop rotation, conditions maintained, and growth progress, so that if errors are made, they will not be repeated.

A "growing schedule" should be developed to aid in planning the greenhouse crop rotation and in making

Table 9-11.—*Effect of top pruning and needle clipping on initial development and field performance of southern pine seedlings*

Pruning treatments	Initial seedling characteristics				Field performance[2]	
	height	diameter	top wt.	root wt.	survival	size
	-------- *mm* --------		-------- *mg* --------		*percent*	*cm*
Longleaf pine[1]						
Control	.....	3.4	1,100	158	51	1.52
10 cm, 15 cm	.....	2.9	393	122	48	1.17
10 cm, 20 cm	.....	3.3	668	148	44	1.40
10 cm, 15 cm, 20 cm	.....	3.3	526	144	54	1.50
Loblolly pine						
Control	229	2.6	722	188	76	58.2
10 weeks	176	2.7	745	203	81	54.3
12 weeks	141	2.7	605	183	78	52.4
14 weeks	133	3.0	499	180	77	49.1
Slash pine						
Control	275	3.0	1,166	212	73	62.8
10 weeks	163	2.8	621	171	78	55.5
12 weeks	136	3.0	590	213	81	56.4
14 weeks	131	2.8	457	179	75	52.1

[1] Longleaf seedlings needles were clipped to 10 cm at about 8 weeks; other treatments were clipped to 15 or 20 cm at 2-week intervals. Loblolly and slash seedlings were pruned to 12.5 cm at 10, 12, and 14 weeks.

[2] Field performance was measured 2 years after outplanting; root collar diameter of longleaf and total height of loblolly and slash pines.

maximum use of space and equipment. The growing schedule is a chart of the conditions to be maintained and operations to be done as a function of calendar date, from seed preparation to shipment from the nursery (Tinus and McDonald 1979). It should incorporate much of what is known about the growing of a particular crop and having it in proper physiological condition on the required shipping date. Consideration must also be given to the growing schedule when designing the facility to ensure that the greenhouse will be able to maintain the required conditions. The growth cycle for the species must be considered, including dormancy and hardening-off needs.

10.1 Features of a Growing Schedule

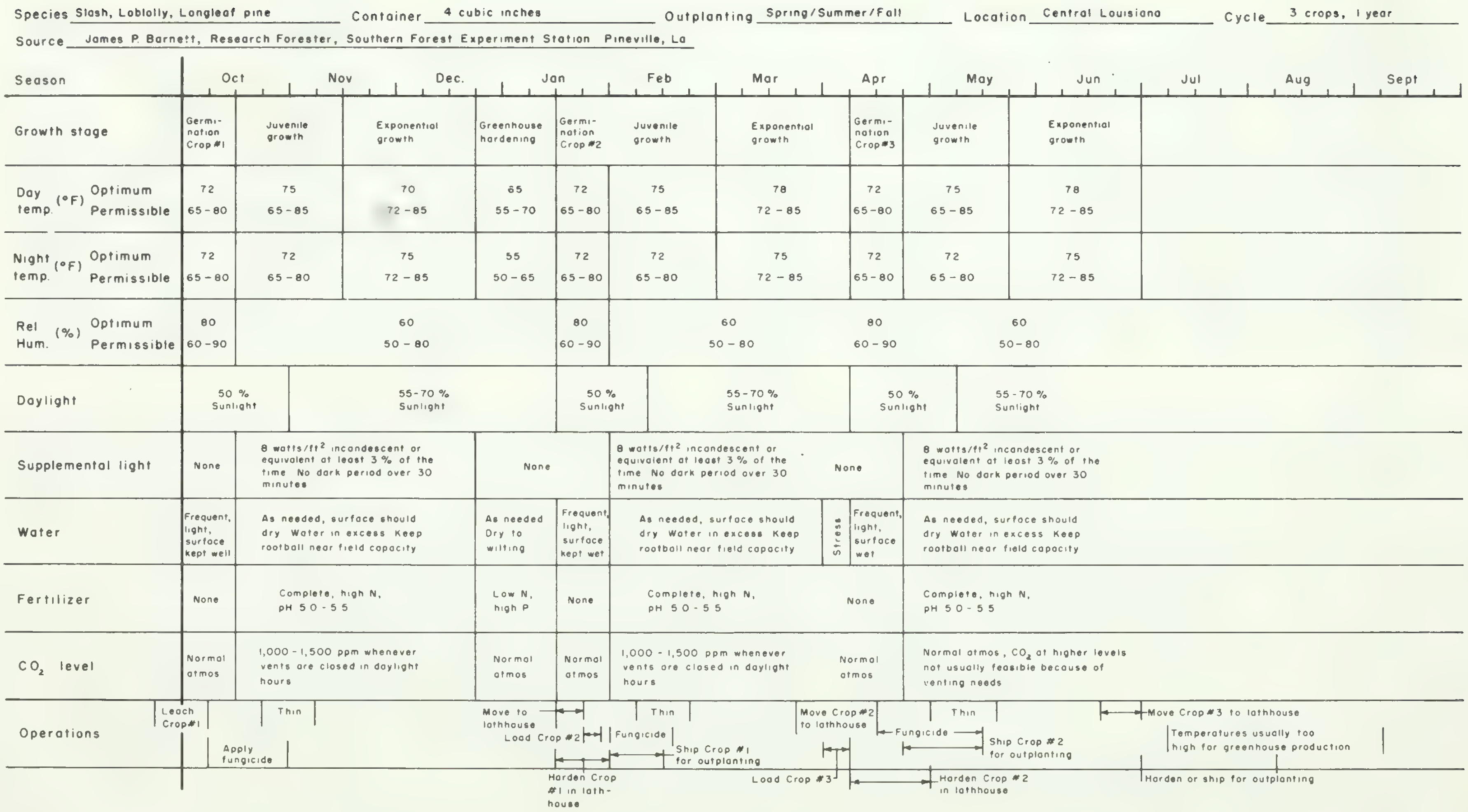
Figure 10-1 is an example of a growing schedule developed for producing three crops of southern pines per year. Time is on the horizontal axis at the top and the factors to be controlled and operations to be performed are listed on the vertical axis at the left. A growing schedule shows the environmental conditions surrounding the growing plant at any given time. By reading the time season line and estimating the time needed for each of the indicated management activities beneath it, the length of time in the different growth stages can be determined.

Tinus and McDonald (1979) list several common features that all growing schedules should have:

1. They should define the dates between which the crop will be in the greenhouse, the crop conditions at any time during the growth cycle, targets for height, caliper, and other indicators of growth stage, and the condition of the environment in the greenhouse at any given time during the growth cycle.
2. The environmental control designated in the growing schedule should be based on the best biological information available for that particular species. The full capability of the greenhouse environmental modification system should be used to meet these growth optimization guides.
3. The growing schedule should show the complete cycle from seed to crop maturity, even if the crop is moved to a shadehouse partway through its schedule.
4. The length of each segment of the growing schedule and the calendar dates it covers should be defined. This is valuable not only for reference while the crop is being reared, but also to record the true length of time needed to produce a satisfactory crop. Records of the length of time and cultural modifications necessary to rear good crops of trees are valuable for more precise growing schedule formulation for future crops.

10.2 Relating the Schedule to Condition and Rate of Crop Development

The species and required size for outplanting determine the container size, seedling density, and the time required to grow it. The site on which the seedling is planted and the time of year you plant determine the required physiological condition of the tree when it leaves the nursery.



Species Slash, Loblolly, Longleaf pine Container 4 cubic inches Outplanting Spring/Summer/Fall Location Central Louisiana Cycle 3 crops, 1 year

Source James P. Barnett, Research Forester, Southern Forest Experiment Station Pineville, La

Season: Oct Nov Dec. Jan Feb Mar Apr May Jun Jul Aug Sept

Growth stage	Germination Crop #1	Juvenile growth	Exponential growth	Greenhouse hardening	Germination Crop #2	Juvenile growth	Exponential growth	Germination Crop #3	Juvenile growth	Exponential growth	
Day temp. (°F) Optimum	72	75	70	65	72	75	78	72	75	78	
Day temp. (°F) Permissible	65-80	65-85	72-85	55-70	65-80	65-85	72-85	65-80	65-85	72-85	
Night temp. (°F) Optimum	72	72	75	55	72	72	75	72	72	75	
Night temp. (°F) Permissible	65-80	65-80	72-85	50-65	65-80	65-80	72-85	65-80	65-80	72-85	
Rel Hum. (%) Optimum	80	60			80	60		80	60		
Rel Hum. (%) Permissible	60-90	50-80			60-90	50-80		60-90	50-80		
Daylight	50 % Sunlight	55-70 % Sunlight			50 % Sunlight	55-70 % Sunlight		50 % Sunlight	55-70 % Sunlight		
Supplemental light	None	8 watts/ft^2 incandescent or equivalent at least 3 % of the time. No dark period over 30 minutes		None		8 watts/ft^2 incandescent or equivalent at least 3 % of the time. No dark period over 30 minutes		None	8 watts/ft^2 incandescent or equivalent at least 3 % of the time. No dark period over 30 minutes		
Water	Frequent, light, surface kept well	As needed, surface should dry. Water in excess. Keep rootball near field capacity		As needed. Dry to wilting	Frequent, light, surface kept wet	As needed, surface should dry. Water in excess. Keep rootball near field capacity	Stress	Frequent, light, surface wet	As needed, surface should dry. Water in excess. Keep rootball near field capacity		
Fertilizer	None	Complete, high N, pH 5.0-5.5		Low N, high P	None	Complete, high N, pH 5.0-5.5		None	Complete, high N, pH 5.0-5.5		
CO$_2$ level	Normal atmos	1,000-1,500 ppm whenever vents are closed in daylight hours		Normal atmos	Normal atmos	1,000-1,500 ppm whenever vents are closed in daylight hours		Normal atmos	Normal atmos, CO$_2$ at higher levels not usually feasible because of venting needs		

Operations:

Leach Crop #1

Apply fungicide

Thin

Move to lathhouse

Load Crop #2

Harden Crop #1 in lathhouse

Thin

Fungicide

Ship Crop #1 for outplanting

Move Crop #2 to lathhouse

Load Crop #3

Fungicide

Thin

Ship Crop #2 for outplanting

Harden Crop #2 in lathhouse

Move Crop #3 to lathhouse

Temperatures usually too high for greenhouse production

Harden or ship for outplanting

Figure 10-1.—*A growing schedule for producing three crops of southern pine per year; vertical lines refer to time of the month (adapted from Tinus and McDonald 1979).*

To determine the sowing date, start with the date the end product must be ready to ship, and work back in time. After the seedlings have reached the desired size, they may need hardening. The amount of hardening needed depends on the season of outplanting and the size and condition of the seedlings.

10.2.1 *Stages of Hardening*—There are several different stages of hardening, and the stage required at shipping depends upon which season the seedlings are to be outplanted.

Succulent seedlings have had no hardening. Their top growth is very active, and the upper part of the stem is not lignified. They are tender and can be used only in the most favorable weather on the best sites. When used judiciously, these seedlings will continue growth without interruption, and no time for hardening needs to be allotted in the growing schedule.

Resting seedlings have arrested shoot growth, and stem tissue may be lignified. These are normally succulent seedlings that have been moisture and/or temperature stressed prior to shipping. They can be planted under more adverse conditions than the succulent seedlings and will resume top growth if outplanted in the late spring or summer when favorable growing conditions occur.

Dormant seedlings have set bud, and all of the stem tissue has lignified, but they are not cold hardy. This degree of hardening takes 3 to 5 weeks to produce and is sufficient for planting in summer or early fall when frosts are not expected. Normally, there will be no top flush until the following year.

Fully hardened seedlings are dormant, with well developed winter buds. They have reached a high degree of cold hardiness, and the chilling requirements for bud break have either been met or will be by the time warm weather arrives at the planting site. This condition requires 6 weeks to achieve and is generally needed for late fall or winter planting. The seedlings can be expected to put on a large flush of top growth the first season in the field.

10.2.2 *Stages of Growth*—By the date the seedlings must be at their full height and ready for hardening or shipment, they will have passed through three growth stages.

Germination begins when the seed is placed in warm, moist potting mix and it should be complete in 10 to 14 days. If not, either the seed has not been properly prepared, or the seed is poor. Prompt and complete germination in the greenhouse nursery is important. Any delay is costly.

Juvenile growth begins when the seed is exhausted and the tree becomes autotrophic. There frequently appears to be a pause in growth as the seedling forms a rosette above the cotyledons. The first green leaves are frequently different in shape, size, and ontogeny from the ones on a mature plant No buds are visible. The seedling grows continuously The length of this stage varies from a few days to several weeks, depending on the species and seed source.

Exponential growth occurs after the seedling has fully taken hold. Frequently the seedlings will begin to resemble a mature tree. The length of this stage is determined by how close growing conditions are to optimum, how large a tree is desired, and how soon one or more growth factors becomes limiting.

The time required for each growing stage can be easily determined if the nurseryman has growth curves and a table of optimum conditions for the species he is growing. Moving backward in time through these three growth stages establishes when to set the seeding date to fit the schedule.

You must also allow time for seed preparation. Does it require stratification, water soaking, or other time consuming treatment? Finally, consider seed collection and proper storage, which brings us to the beginning of the growing cycle.

10.2.3 *Timing Overlapping Schedules*—Given the date at which the product is needed, once it is known how rapidly the seedlings will grow and how rapidly they will complete all of the required stages, it is easy to establish the dates at which each stage must begin These dates may need to be adjusted to allow one crop to mesh with the next, and to coordinate the use of space and manpower. If the trees will remain in the greenhouse from sowing until shipment, the only requirement is that they be shipped in time to start the next crop. If shipment is delayed, the seedlings may need to be moved to a temporary holding area. If the trees are to be moved to a shadehouse for part of their stay at the nursery, they must be able to tolerate conditions there. If the trees are fully hardened, they can be moved to the shadehouse at any time.

10.2.4 *Necessary Growing Data*—The optimum conditions for each stage of growth are not generally known for the southern pine species. Certain pertinent information is known, of course, but the grower is well advised to develop specific information for the species, environment, and growing regime at each facility. This information can be used to refine the growing schedule to meet each specific situation.

The growth record from Tinus and McDonald (1979) is a useful tool to use in developing growth response data (fig. 10-2). In addition to information recorded on this form, it is very useful to supplement this with xerographic copies of seedling development (fig. 10-3) information about seed source, size, and growth history can be put on the same sheet with the seedling image. This provides a useful record of development over time and under various environmental and cultural conditions.

GROWTH RECORD

Greenhouse No.________________ Species________________________

Seed lot________________________

Date	Height	Caliper	Weight	Comments

Figure 10-2.—*Form for recording growth data.*

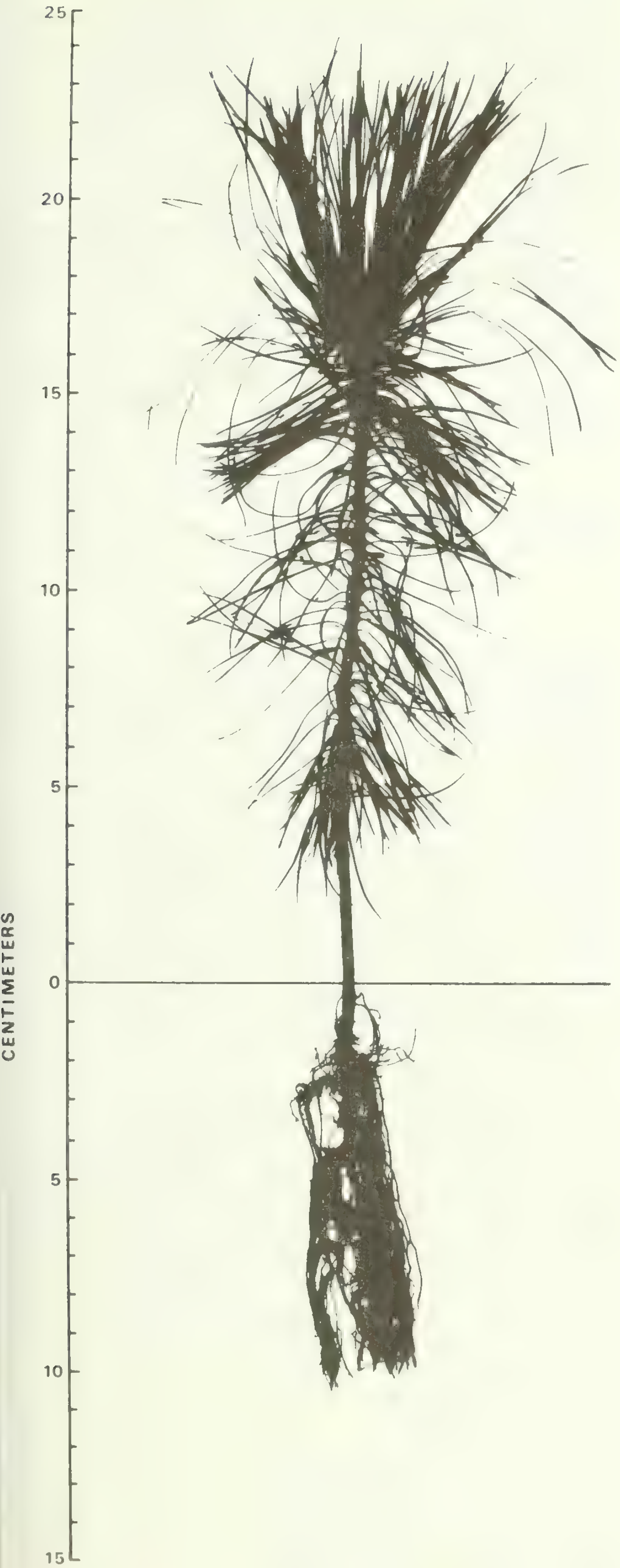


Figure 10-3.—*Loblolly pine seedling development.*

11. DESIRED SEEDLING CHARACTERISTICS

Containerized seedlings of low vigor or poor quality can survive if soil moisture and other planting site conditions are near optimal. However, when less favorable conditions are met soon after outplanting, the morphological and physiological conditions of the outplanted seedlings are closely related to their ability to survive. A number of workers have noted that large and woody seedlings survive and grow better than smaller seedlings on difficult sites or where competition is severe (Iverson and Newton 1980, Davidson and Sowa 1974, Walker and Johnson 1980, Barnett 1974d). Southern pine seedlings are usually large enough at 12 to 14 weeks to perform well in the field. A few more weeks of growth may be desired when planting more difficult sites. Age alone, however, is not a reliable criterion of when to plant, because seedling development varies greatly by season, facility, and cultural treatment.

Almost 30 years ago, Wakeley (1954) established a grading system based on morphology for bare-root southern pine seedlings. This grading system, based primarily on height, diameter, and nature of the stem, is still the best available. However, because there are basic differences in age, development, and cultural regimes between bare-root and container-grown seedlings, grades established for bare-root stock may not be the same as for those grown in containers. Over the past several years we have tried to determine which morphological characteristics of containerized seedlings relate directly to field performance.

11.1 Characteristics to Consider

A variety of seedling characteristics have been directly related to field performance at one time or another. These include: shoot-to-root ratio, height, stem diameter, dry weight, chlorophyll content, secondary needles, and mycorrhizal development. The value of these measurements as indicators of performance for container-grown seedlings varies greatly.

11.1.1 *Shoot-to-Root Ratios*—Seedlings usually have been reared with the view that the ideal seedling shoot-to-root ratio should be between 1 and 2 (Ferdinand 1972, Wakeley 1954). Recent work by Walker and Johnson (1980) with northern species of spruce and pine shows that much higher shoot-to-root ratios may be desirable for container-grown seedlings. Regression analyses of their data indicate that the weight obtained 1 year after planting is proportional to initial seedling weight and shoot-to-root ratio; larger seedlings with shoot-to-root ratios of up to 7.4 had significantly greater weight increases than smaller seedlings with ratios of 2.0. A similar relationship was found with the southern pines when shoot-to-root ratios were related to seedling height (fig. 11-1).

It is apparent from the data shown in figure 11-1 that a so-called "balanced" seedling is not necessary or even desirable with container-grown plants. Studies by McGilvray and Barnett (1982) with container-grown southern pines indicate that higher shoot-to-root ratios are more a function of larger shoots than variations in root size. They concluded that the shoot-to-root ratio is generally not a meaningful criterion when evaluating containerized southern pine seedlings.

11.1.2 *Chlorophyll Content*—Chlorophyll content in seedling needles has been shown to give an estimate of stock quality (Linder 1980). McGilvray and Barnett (1982) found the chlorophyll content of the needles at planting was correlated to the height of the pine seedlings 1, 2, and 3 years later (table 11-1). In this particular study, high chlorophyll content related well to seedling vigor. However, different nutritional regimes were practiced during the greenhouse growing period, and thus differences in seedling quality may have been due to a close relationship between chlorophyll and nitrogen contents. Chlorophyll is generally a nonspecific indicator that is influenced by many factors. When seedlings are grown with abundant nutrients, chlorophyll content may not be closely related to field performance.

11.1.3 *Mycorrhizae*—The visible presence of mycorrhizae on slash and loblolly pine seedlings indicates increased survival of nursery stock (Jorgensen and Shoulders 1967, Shoulders and Jorgensen 1969). The amount of mycorrhizae can have a significant effect on survival and growth of southern pine nursery stock.

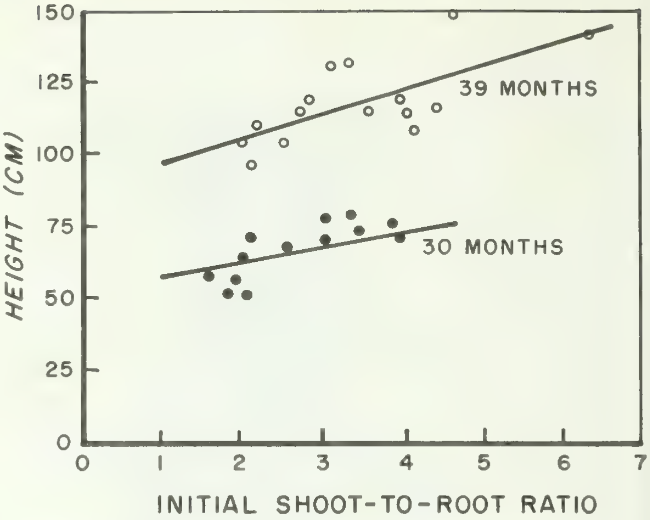


Figure 11-1.—*Initial shoot-to-root ratio and seedling height relationships 30 and 39 months after outplanting of loblolly pine.*

The need for mycorrhizal development on container-grown seedlings is probably not as great as with bare-root plants because the root system remains intact when planted, and initial stress conditions are less severe. Shortleaf pine seedlings grown in contain-

Table 11-1.—*Summary of correlation coefficients relating initial seedling development to field performance (from McGilvray and Barnett 1982)*

Seedling characteristic[1]	Survival 1977	Survival 1978	Survival 1979	Height 1977	Height 1978	Height 1979
Loblolly pine						
Height	0.021	0.238	0.324	0.972*[2]	0.743*	0.738*
Diameter	.168	.361	.455	.913*	.819	.833
Root weight	−.345	−.259	−.339	−.078	−.225	−.259
Stem weight	.049	.294	.315	.870*	.646*	.655*
Chlorophyll	.235	.418	.595*	.771	.915*	.899*
Longleaf pine[3]						
Diameter	.079	.046	.020	−.106	−.112	−.162
Root weight	.534*	.522*	.479	−.396	−.435	−.431
Stem weight	−.252	.296	.176	.548*	.590*	.555*
Chlorophyll	−.418	−.566*	.443	.866*	.810*	.798*
Shortleaf pine						
Height	.052	.147	.283	.929*	.829*	.784*
Diameter	−.142	−.058	.099	.761*	.760*	.687*
Root weight	.170	.157	.182	−.061	−.021	−.057
Stem weight	.030	.128	.249	.773*	.743*	.666*
Chlorophyll	.281	.193	.302	.913*	.861*	.832*

[1] Seedlings outplanted June 22, 1976; all measurements taken during the month of February.

[2] An asterisk represents statistical significance at the 0.05 level.

[3] Longleaf growth was evaluated by measuring root-collar diameter rather than height.

ers and inoculated with *Pisolithus tinctorius* and *Thelephora terrestris* mycorrhizae did not survive or grow better than those that were not inoculated when outplanted on dry sites in the Ouachita Mountains of Arkansas (Ruehle and others 1981). In fact, performance of inoculated seedlings with over 50 percent root infection was no better than for seedlings grown under a high fertility regime where only 16 percent of the roots showed mycorrhizae. The presence of mycorrhizae on root systems becomes more important as the planting sites become more difficult. Goodwin (1980) reported that inoculation with *Pisolithus* increased field performance of container-grown loblolly and Virginia pine on an adverse borrow site.

11.1.4 *Secondary Needles*—The development of fascicle or secondary needles is one criteria used by Wakeley (1954) in his seedling grading system for nursery stock. Tests with container-grown southern pines show that the presence of secondary needles is an important indicator of seedling development (Barnett 1980a). Secondary needles develop when the stem becomes woody and stiff. This condition represents a stage when the seedlings become more hardy and less susceptible to cold and drought damage. Thus, seedlings that have secondary needles are more vigorous than those that have not yet reached this stage of development.

11.1.5 *Stem diameter*—Stem diameter was shown to be a characteristic closely related to seedling development of loblolly and shortleaf pine (table 11-1). Other tests (McGilvray and Barnett 1982) confirmed the relationship of loblolly pine stem diameter to seedling growth after outplanting. Although stem diameter was not consistently related to field survival, when combined with other easily measured characteristics, predictions of field performance should improve.

11.1.6 *Seedling Heights*—The height of a seedling when outplanted is generally a good indicator of subsequent field performance (Walker and Johnson 1980, Iverson and Newton 1980). Studies with container-grown southern pines confirm this observation (table 11-1). Not only is height at the time of outplanting closely related to subsequent heights, it is also correlated to incremental growth for a number of years (table 11-2). How long this relationship will hold is open to question. Blair and Cech's (1974) work with slash pine nursery stock has shown that Wakeley's Grade 1 and 2 seedlings produced significantly more volume after 13 years than Grade 3 seedlings (fig. 11-2). In Wakeley's morphological grades, height is a major criterion, with the lower grades exhibiting greater seedling height. Similar results have been published for loblolly pine after 30 years (Wakeley 1969).

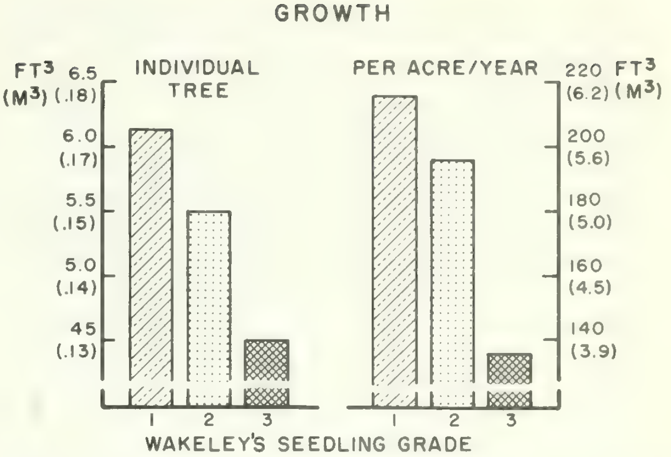


Figure 11-2.—*Volume performance of graded slash pine seedlings after 13 growing seasons (Blair and Cech 1974).*

Heights and diameters should both be considered when developing predictions of field performance. If containerized seedlings are grown at high seedling densities, heights may be about the same as when grown at lower densities, but stem diameters of the seedlings grown at the lower densities will be larger, and seedlings with larger stem diameters perform better in the field (Barnett 1980b).

11.1.7 *Dry Weights*—Dry weights of seedling stems at the time of outplanting were proportional to heights in the field over several years (tables 11-1, 11-2), but were not closely related to survival. Positive correlations of dry weights of roots at outplanting to survival did not occur consistently. Correlations of both height and growth to total seedling dry weight did occur with loblolly pine in another study (table 11-2). Differences in response among studies seem related to environmental conditions at or shortly after planting.

Table 11-2.—*Correlation coefficients of morphological characteristics of loblolly pine seedlings at time of outplanting with heights and growth in the field*

Seedlings characteristic[1]	Height			Growth/year		
	Year 1	Year 2	Year 3	Year 1	Year 2	Year 3
Height	0.864[2]	0.814	0.829	0.490	0.770	0.840
Stem diameter	0.899	0.864	0.832	0.579	0.826	0.842
Root weight	0.700	0.641	0.628	0.386	0.594	0.582
Stem weight	0.890	0.837	0.847	0.536	0.790	0.846

[1] Outplanted February 1976.

[2] All values shown are statistically significant at the 0.05 level.

11.2 Suggested Characteristics for Loblolly Pine

There is an insufficient amount of data available to specify which characteristics of containerized southern pine seedlings are necessary to obtain maximum survival and growth when outplanted. Our best information is for loblolly pine, but these data are from studies not designed to provide predictive equations relating initial seedling quality to field performance. However, these data are probably the best available for the southern pines and will give some feel for the relationship between morphology and growth.

There is considerable difference in measurement ease and reliability of the various seedling characteristics that relate to field performance. Characteristics such as chlorophyll content, dry weights, and shoot-to-root ratios are not as easy to determine as are seedling heights or diameters. Results indicate that simplification of measurements may be feasible. For example, seedling stem diameter at the time of outplanting is closely related to initial height (fig. 11-3). This initial stem diameter is also related to seedling heights in the field 2 and 3 years after planting (fig. 11-4). Correlations of stem dry weight with height after outplanting are also significant (fig. 11-5), and these correlations are similar to those that relate initial height to field heights 1, 2, or 3 years later (fig. 11-6).

As long as the type of container and cultural treatment remain constant and provide for good quality seedlings, height at the time of outplanting seems to be the best single morphological indicator of field performance. In addition, it is easily measured. Other visual criteria, such as presence of secondary needles and woody tissue, should also be taken into consideration.

The correlations of seedling diameters, stem weights, and heights at the time of outplanting all indicate that, within the range of the data, field performance improves as size at the time of outplanting increases. Not only are seedling heights greater in the field after several years, but yearly growth several years after outplanting is affected (fig. 11-7).

This indicates that larger seedlings perform better in the field. However, these results reflect a limited range of initial seedling sizes—from about 7.6 to less than 23 cm (3-9 in) in height. Also, it is expected that a point exists after which larger seedlings do not result in greater field growth.

Additional data with larger initial seedling sizes (18-33 cm; 7-13 in), show that in this larger size range, no correlation occurs with field heights (fig. 11-8). Thus, biologically as well as economically, there are practical limitations as to how large seedlings should be at outplanting.

11.3 Summary of Minimum Specifications

A number of seedling characteristics were closely related to growth in the field. Of these, height was directly related to field performance and is the most easily measured. A combination of heights and other characteristics is probably desirable when seedlings are evaluated after being grown under varying container, cultural, and environmental conditions. For loblolly pine seedlings, heights of 15 to 20 cm (6-8 in), presence of secondary needles and woody tissue, and diameters of 1.5 to 2.5 mm (0.06-0.10 in) at the time of outplanting should result in excellent survival and growth.

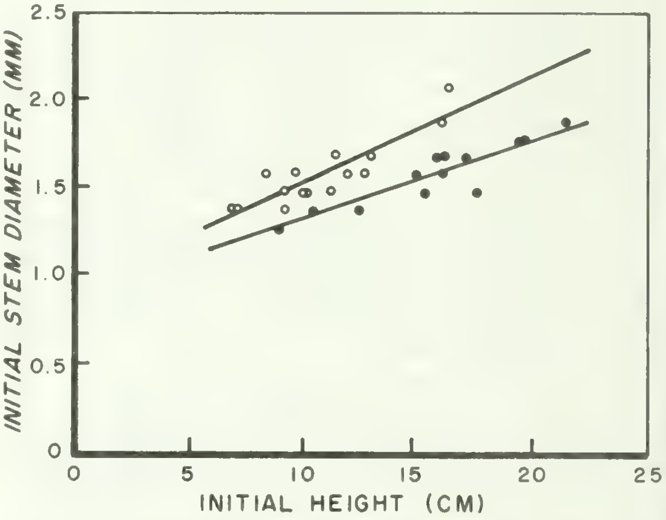


Figure 11-3.—*Relationship of initial height and initial stem diameter for loblolly pine seedlings, based on two separate outplantings.*

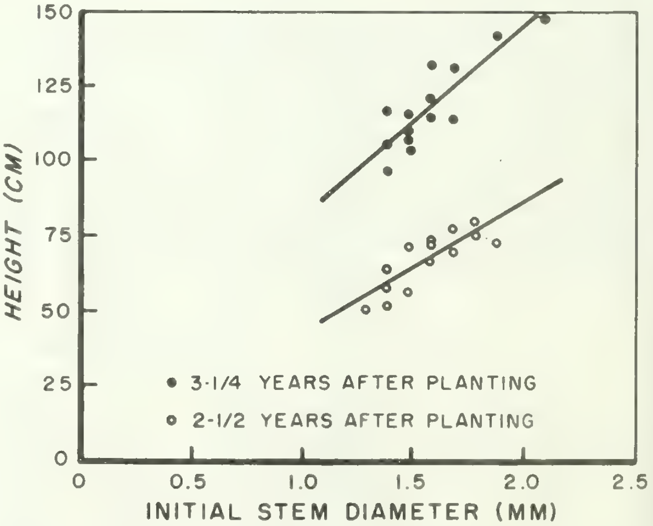


Figure 11-4.—*Relationship of initial stem diameter and height 2-1/2 and 3-1/4 years after outplanting for loblolly pine seedlings.*

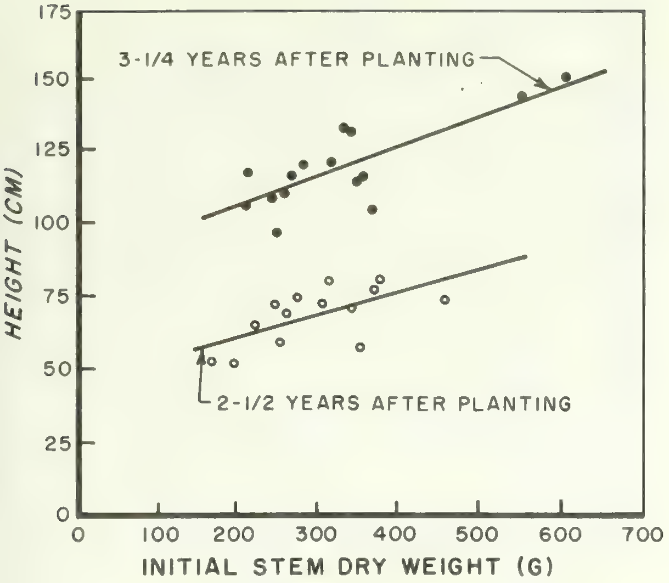


Figure 11-5.—*Relationship of initial dry weight and seedling height 2-1/2 and 3-1/4 years after outplanting for loblolly pine seedlings.*

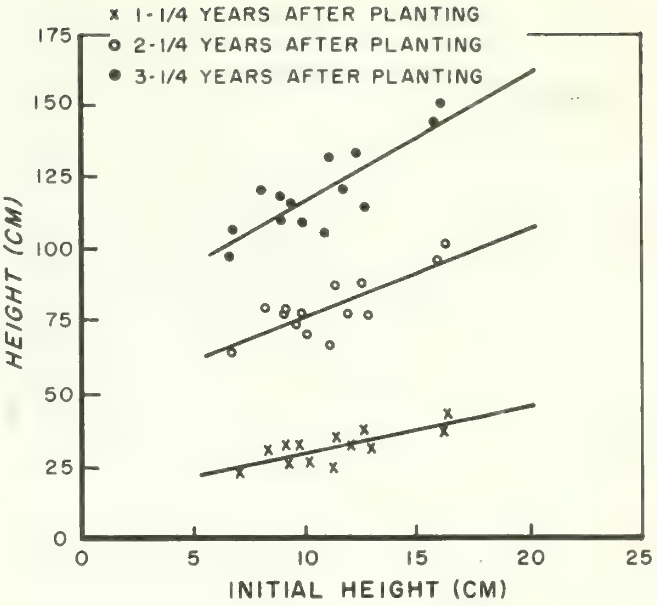


Figure 11-6.—*Comparison of initial seedling height to future height for loblolly pine seedlings.*

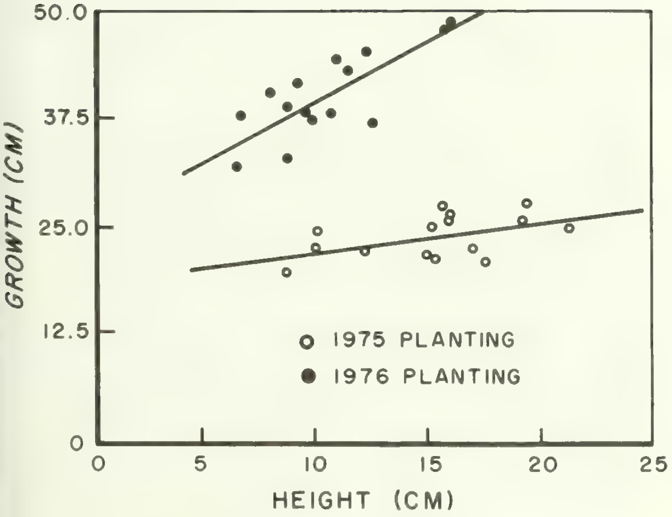


Figure 11-7.—*Relationship between initial height and growth over a 1-year period (Feb. 1978 to Feb. 1979) for loblolly pine seedlings based on two outplantings.*

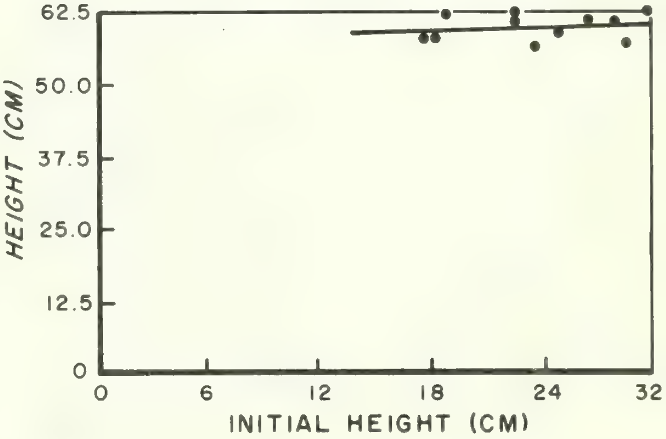


Figure 11-8.—*Initial height and field height relationship for loblolly pine seedlings 1-1/2 years after outplanting.*

12. PROCESSING, HANDLING, AND PLANTING

12.1 Extraction from Containers

Once high quality containerized stock is produced, growers face the equally demanding task of maintaining that quality until planting. How stock is processed will depend upon what type of container is used. If seedlings are grown in tubes or blocks, they are shipped and planted in their containers. If seedlings are grown in plug-type containers, a decision must be made whether or not to extract them from the containers before shipment. Both techniques have inherent advantages and disadvantages.

The advantages of extracting seedlings from plug-type containers include significantly less shipping and storage volume, the ability to grade the root system as well as the seedling shoot, and not having to return the containers to the nursery. Disadvantages of this system are also significant, however. To avoid a serious reduction in stock quality, extracted seedlings must be completely dormant and cold-hardy (Landis and McDonald 1982). For southern pines this would be difficult, and the planting of extracted plug seedlings would be restricted to essentially the same planting season as for bare-root stock, thus nullifying the advantage of extending the planting season with container stock.

When seedlings are left in the container for shipping and handling, the root plug will receive maximum protection with the opportunity for more rapid establishment once outplanted. Leaving seedlings in the container until they are planted also allows for handling of nondormant stock necessary for extending the bare-root planting season. Disadvantages of this system are the increase in volume of material shipped and stored, which often includes empty cells, and seedlings can only be graded on shoot characteristics. Also, containers must be returned to the nursery, which is expensive and invariability results in some container damage.

Both system can be used to their greatest advantage. Seedlings shipped prior to becoming sufficiently cold-hardy, and those shipped in the spring after shoot growth has begun, should be left in the container until planting. Containerized seedlings shipped while dormant can be extracted and wrapped in bundles or packed in boxes. The Ray Leach single cells offer a unique alternative. These individual plastic containers can be removed from the growing racks and shipped much like extracted seedlings, but the container protects the root plug until planting. The empty cells must still be returned to the nursery for reuse.

12.2 Transporting Seedlings

Refrigerated transportation is best for either extracted seedlings or those shipped in the container. However, if refrigerated transport is not available, enclosed vehicles, slat-sided trucks, or trailers with tarpaulin tops can be used. Air circulation among seedlings is essential to prevent overheating. This can be accomplished by leaving the back of the vehicle open or by some other method that provides airflow without subjecting the seedlings to the wind created by highway speeds. Air temperature around the seedlings should not be allowed to exceed 29 °C (85 °F). In unrefrigerated trucks or trailers, monitor temperatures at the beginning and end of the haul. If the trip is longer than 3 or 4 hours, check the temperature around the seedlings periodically. If temperature in the vehicle begins to get too warm, it may be necessary to find a shady place and water the seedlings if possible. In hot weather, haul seedlings at night. Even for short trips, containerized seedlings should not be exposed in open trucks or trailers because they are susceptible to rapid desiccation and overheating.

For economy and efficient use of space, trucks or trailers should be fitted with racks or stacking pallets (Guldin 1983, Luchkow 1982). When shipping in boxes, the seedling boxes must be designed for proper stacking strength and size. Improperly designed boxes can waste valuable and costly cargo space (Hoehnke 1974). At the nursery, pallets can generally be loaded with a forklift. At the planting site, unloading can best be handled if the truck or trailer is fitted with a hydraulic tailgate and small swiveling crane.

Be sure that truck and trailer beds used for seedling transport are clean and clear of gasoline, diesel fuel, pesticides, and sharp implements. These can kill or injure seedlings, tear seedling boxes, or damage containers.

12.3 Care of Seedlings in the Field

Intermediate storage of seedlings between the nursery and the planting site should be avoided. Prompt planting, especially when seedlings are not dormant, is often the key to reforestation success. However, temporary storage, either enroute or at the planting site, is common due to weather or changes in planting schedules. If seedlings are shipped in a refrigerated vehicle, that vehicle makes an excellent temporary cold storage facility. If refrigerated storage is not available, a simple lean-to, unheated barn, or even a shady spot is better than exposing seedlings to direct sun. Do not forget to allow for adequate air circulation to prevent overheating. Monitoring the temperature of seedlings stored in boxes or bags is especially critical. Temperatures above 27 °C (80 °F) can initiate mold and decay, and 48 °C (118 °F) for 2 hours is lethal to loblolly pine seedlings (Ursic 1961).

In cold weather, containerized seedlings should also be protected from freezing. Under natural conditions, seedling root systems are well insulated by the soil and do not attain the same level of cold-hardiness as the shoots. However, containerized seedlings waiting to be planted in the field can be subjected to low temperatures that will be lethal to their roots. Moreover, cold damage to roots is not as obvious as cold damage to shoots. Root mortality will not be observed until the shoots are placed in an environment favorable to growth. In an Arkansas study, survival was less than 50 percent for containerized seedlings exposed to −10 °C (14 °F) in February, compared to greater than 90 percent survival of seedlings from the same crop that were moved inside prior to the low temperature (Mexal and Carlson 1982). Styrofoam-type containers provide greater insulation from temperature extremes than hard plastic containers, tubes, or blocks.

Because of the relatively small volume of media containerized seedlings are grown in, they are very susceptible to desiccation and must be protected from the drying influences of the sun and wind. Extracted and packaged seedlings should be handled much like bare-root seedlings; that is, they should be kept shaded, the packages reclosed if opened, and watered when necessary to keep the root plug moist. Seedlings shipped in the container should be thoroughly watered at the nursery and rewatered as necessary to maintain the media at field capacity until planting.

12.4 Selecting and Preparing Suitable Planting Sites

As indicated in Chapter 3, containerized seedlings perform as well as, or better than, bare-root stock on a variety of sites. Due to limitations of planting season or seedling physiology, bare-root stock does not always survive and grow well when planted on such adverse sites as wet flatwoods, deep sandy soils, highly erodible fragile soils, spoil banks from mining operations, and drier tension-zone soils (Barnett 1980a). Containerized seedlings, however, have performed well under such adverse conditions in the South (Amidon and others 1982, Barnett 1975, Goodwin 1980, Ruehle 1982a). These successes can be attributed to more rapid establishment of the undisturbed root system or to planting during a season when advantage can be taken of more favorable planting conditions on a particular site. As with bare-root seedlings, success depends on using the most appropriate species and seed source for the intended planting site.

12.4.1 *Site Suitability*—Several environmental factors must be considered before planting containerized seedlings, especially on adverse sites or outside the normal planting season. Factors that will affect planting success include: soil characteristics such as texture, moisture, and nutrient availability; degree of site preparation; probable air and soil temperature at planting time and during seedling establishment; competition for moisture and light; and seedling pests (Hite 1976).

Available soil moisture is the most critical factor in evaluating the suitability of a site for planting. Soil texture and moisture content determine the soil water potential, which is a measure of the amount of water in the soil available for plant growth. At field capacity, soil water potential is about −0.3 bars. As soil moisture becomes less available, soil water potential becomes more negative. A planting site should be considered high risk if its soil water potential is −10 bars or less (Hite 1976). Soil water potential can be determined with a portable tensiometer or by obtaining pressure chamber measurements of plant water potential taken before sunrise from established vegetation on the site.

Tensiometer and pressure chamber readings, however, do not indicate the rate at which soil water potential is likely to change. Soil water potential will decrease more rapidly in sandy soils or when the weather is hot and dry than in clay soils or under cool, humid conditions. With advanced planning, soil moisture retention curves can be developed by a soils laboratory for specific planting sites or generalized by soil types. These curves indicate the rate of water depletion from the soil. Tensiometer or pressure chamber readings can then be used to determine where the current soil moisture potential of the site is located on the curve. Thus, an estimate is obtained of how much water is available in the soil and how long it will last (Legard 1977). Such detailed site evaluation is especially valuable if the intended planting site is particularly severe or if planting under droughty conditions is anticipated.

12.4.2 *Site Preparation*—The degree of site preparation can have dramatic effects on the performance of outplanted seedlings. Site preparation prior to planting can be designed to do any or all of the following: reduce slash residues, limit vegetative competition, or alter the microsite to enhance seedling performance. Since containerized seedlings are generally smaller than bare-root stock, competition control is a particularly important aspect of site preparation. In a comparison study on a low-competition site, containerized shortleaf pine had 2.5 times the plot volume index of bare-root seedlings (Ruehle and others 1981). But on a site with dense herbaceous vegetation, containerized seedlings had only 60 percent of the plot volume index of bare-root seedlings.

In another study, loblolly pine seedlings planted in July survived better on mechanically prepared sites than on a fresh burn, particularly when planted on a silt-loam soil where herbaceous growth following the burn resulted in severe competition (table 12-1) (Barnett 1980a). On the silt-loam soil, a 1-foot wide scalped area was as effective as disking in increasing survival, but disking was more effective in promoting height growth. On a sandy-loam soil where competition was less severe, fewer differences in survival were related to site preparation. Again, disking was the most effective treatment in promoting height growth.

The amount of site preparation necessary also differs by species. Longleaf pine seedlings are more intolerant of competition than the other southern pines, so their survival and growth are enhanced by more intensive site preparation (Barnett 1974a).

12.5 Planting Techniques

Despite their bulk and weight, ease of planting is one of the most attractive features of containerized seedlings. The uniformly shaped root systems of container-grown seedlings are easy to plant by hand or by machine, with the potential for automated planting much greater than for bare-root stock. Descriptions of available hand planting tools and planting machines have been compiled by Larson and Hallman (1980). A discussion of the advantages, disadvantages, and operation of each piece of equipment is provided in addition to a list of suppliers.

12.5.1 *Hand Planting*—Containerized seedlings can be hand planted with conventional bare-root planting tools or with tools designed for specific container types. Specially designed planting tubes, such as the Finnish Pottiputki® and the Walter's gun from British Columbia, have been used to plant container stock at up to twice the rate of hand planting bare-root stock (Appelroth 1971, Vyse 1971, 1973). These planters work by displacing or dibbling the soil to make room for the seedling root ball, with the effectiveness depending a great deal on the soil type and soil moisture. They work well on midrange soil types such as sandy loam, loam, and silt loam (Edwards 1974). For clay soils, tools must be designed to avoid soil compression or case hardening of the side walls when the hole is opened. For very sandy soils the tool must prevent the side walls from caving in before the seedling can by properly planted. Hand-held power augers can be used for planting stock grown in very large containers.

Removing a soil core with the same configuration as the containerized seedling plug results in better seedling performance in heavy or compacted soils. In Louisiana, loblolly pine seedlings planted in a heavy silt loam soil survived better when the planting hole was cored rather than dibbled (table 12-2) (Barnett 1980a). Survival and height growth of lodgepole pine (*Pinus contorta* Dougl. ex Loud.) in a compacted clay loam with bulk density of 1.9 g/cm^3 (119 lb/ft^3) or higher in Saskatchewan, Canada, was best when a soil core was removed for planting (Bohning 1981). In both studies, seedlings planted in dibbled holes on lighter textured soils or in soils with bulk density of less than 1.6 g/cm^3 (100 lb/ft^3) performed as well or better than seedlings planted in core holes.

When containerized seedlings are properly hand planted, their roots should grow into the adjacent soil in a spatially uniform manner. From 26 plantations on various soil types in Oregon and Washington, Douglas-fir trees were dug up 2 to 4 years after being planted as plug seedlings. The root systems were classified longitudinally and radially into 13 zones, and

Table 12-1.—*Average survival and heights for loblolly pine seedlings on different prepared sites*[1]

Site preparation method	Silt loam soil			Sandy-loam soil		
	Container			Container		
	PP[2]	KTS	S-2	PP	KTS	S-2
			survival (percent)			
Burn	36	40	32	45	78	71
Scalp	68	77	65	51	91	70
Disk	33	73	53	58	92	90
			height (cm)			
Burn	0.40	0.43	0.43	0.31	0.46	0.43
Scalp	0.34	0.49	0.40	0.34	0.43	0.34
Disk	0.43	0.58	0.43	0.40	0.58	0.46

[1] Measurements taken 1½ years after outplanting in July 1978.

[2] PP = Paperpot
KTS = Keyes Tree Start
S-2 = Styroblock-2

Table 12-2.—*Average survival of loblolly pines using two planting methods with three different soils*

Soil type	Planting method	Survival at 2 months	Survival at 18 months
		percent	percent
Beauregard series (silt loam)	Dibbled	86 ab[1]	74 ab
	Cored	90 ab	76 a
Wrightsville series (heavy silt loam)	Dibbled	85 ab	64 b
	Cored	93 a	80 a
Ruston series (sandy loam)	Dibbled	83 bc	73 ab
	Cored	70 c	63 b

[1] Numbers within columns followed by the same letter are not significantly different at the 0.05 level.

on the 325 seedlings excavated, egressed roots were found in an average of 11 of the available zones of the plug mass (Rischbieter 1978). In general, poor root egress was found only where soils had been damaged, aeration was poor, or seedling vigor was markedly reduced due to factors other than soil texture.

12.5.2 *Mechanical Planting*—Most mechanical planters designed for bare-root seedlings can be adapted for planting container stock with only minor modifications. Conventional planting machines are either of the continuous or intermittent furrow type and are usually manually fed. The only modifications necessary for containerized seedlings on continuous furrow machines may be in operator technique, while on intermittent planters some changes to the seedling holding mechanisms may be necessary.

Sophisticated, self-propelled, prototype machines for automatic planting of seedlings grown in particular containers have been developed in Finland and Canada (Kohonen 1982, Pease 1980, Walters and Silversides 1979). These machines plant 2 or 3 seedlings simultaneously and have the capacity to plant up to 3,000 trees per hour, depending on the site. Both the prototypes are capable of scarifying the planting spot just prior to planting the seedling. Although expensive, such machines may be justified for very large scale reforestation activities in areas where hand planting labor is not available or is inadequate. The price a land manager is willing to pay for any planting machine depends on the machine production rate and the local hand planting costs (McKenzie and others 1981). Few potential buyers realize how much they can pay for a tree planting machine when all factors are considered.

12.5.3 *Depth of Planting*—As with bare-root stock, planting containerized seedlings to the proper depth is important to ensure good survival and growth after outplanting. Containerized seedlings should be planted deep enough so that the top of the root plug is covered with about 1 cm (0.4 in) of soil. Covering the container reduces drying in the root zone caused by the wicking effect of the media or planted container. Planting below the ground line also prevents frost heaving of fall-planted container stock (Walker and Johnson 1980).

Care must also be taken not to plant containerized seedlings so deep that the shoot is covered up, especially during machine planting. Control of planting depth is more critical and can be more difficult with container stock than with bare-root seedlings (Robbins and Harris 1982).

12.5.4 *Season of Planting*—One of the greatest potential benefits of containerized seedlings is being able to extend the planting season. In central Louisiana, containerized seedlings have been planted throughout the year. For summer-planted loblolly, slash, and longleaf pines, survival and subsequent growth have been good, even under droughty conditions (Barnett 1980a, Amidon and others 1982). For winter planting of containerized southern pines, it is essential that they receive sufficient hardening-off before outplanting.

Trends in field performance were similar for both loblolly and slash pine container-grown seedlings outplanted monthly from January to September on a silt loam soil (see figs. 5-2, 5-3). The poor survival of loblolly pine planted in January was attributed to the fact that the stock had not been hardened off. The greater average height of bare-root trees compared to containerized trees of both species indicated that the bare-root seedlings had maintained the size advantage they had at planting throughout the three growing seasons of the study.

Caution must be exercised if planting under drought conditions is contemplated. Adequate soil moisture is essential for seedling establishment and survival. Methods of evaluating soil moisture available for plant growth were discussed in section 12.4.1. In addition to estimating soil moisture, weather forecasts should also be considered during the normally hot and dry months from late spring through fall. While planting containerized seedlings during other than the normal planting season has been sucessful, adequate planning and operational flexibility are required.

12.6 Sampling for Quality and Establishment of Evaluation Plots

The use of container-grown stock for reforestation is relatively new in the South. Containerized seedlings are often planted in comparison trials with bare-root stock to determine suitability on particular sites, during specific times of the year, or using various techniques. It is very important that proper sampling and evaluation techniques are used to adequately determine the performance of containerized seedlings in the field.

In many cases the land manager will only be interested in first year stocking or survival. The words stocking and survival are often used interchangably when discussing planting success. The two concepts are different, however. Stocking refers to the number of trees per acre and is often estimated to determine the need for replanting. Survival is the number of living trees at a given time, expressed as a percent of the number of trees planted. Survival estimates are most useful for identifying problem areas and comparing stock types or planting methods.

Stocking is generally estimated by counting the number of live trees on fixed-area circular plots spaced either randomly or systematically over the planting site. Large-scale aerial photography offers a monitoring alternative to such conventional ground surveys. Photographic surveys are faster and may be more economical in some situations. Conifer seedlings 30 cm (12 in) or more in height can be readily indentified during the winter months on imagery at scales of 1:500 to 1:1000 (Ball 1981).

For ground surveys, the number of sample plots required for stocking estimates depends on the plot size, the degree of accuracy desired, and the stocking variability from plot to plot. Sample variability increased with decreasing plot size; therefore 40-m^2 (0.01-acre) plots have been recommended for stocking estimates (Ursic 1960, Xydias and others 1983). Tract size also affects sample variation. Consequently, the practice of specifying one plot per planted 0.4 ha (1 acre) will likely undersample plantings of 12 ha (30 acres) or less and oversample tracts of 40 ha (100 acres) or more (table 12-3) (Xydias and others 1983). If survival data is required from a planting, the best method is to establish and stake the center of the 40-m^2 (0.01-acre) plots at the time of planting. When the plots are established, the number of trees planted is recorded and the number of live trees is tallied after the desired time interval. Survival can then be easily and accurately calculated. Methods of estimating planting rate, such as bale counts or spacing, are seldom accurate enough to be used as reliable indicators of the number of trees in survival calculations (Xydias and others 1983).

To determine if there are differences between stock types or planting methods, as well as for other comparisons, measurements of growth are also important Heights, stem diameters, and dry weights are seedling characteristics useful in evaluating outplant performance.

A simple experimental design of field plots has been recommended that will allow valid, statistical comparisons between two or more variables (Owston and Stein 1974). They suggest locating four plots (replications) within the locality of interest. Site conditions within each plot should be as uniform as possible, but conditions among the plots can be varied or uniform The plots should be accurately mapped.

Each of the four plots should contain two rows of each treatment being studied. For a bare-root versus container comparison, each plot would consist of four rows, two of container-grown trees and two of bare-root seedlings. Each row should contain at least 25 trees. Treatments should be assigned to the rows randomly, and the randomization should be made independently for each plot. The plot corners and row ends should be permanently marked to facilitate relocation and measurement.

Other factors to consider when planning comparison evaluations include: the seed source used, the size of seedlings planted, handling and care prior to outplanting, and postplanting care. If the field plots are laid out as suggested, and the seedlings are treated identically except for those characteristics being compared, differences in performance should be due to the variables tested and not to other factors.

Table 12-3.—*Number of 40-m^2 (0.01-acre) plots required to estimate first-year stocking by area planted (from Xydias and others 1983)*

Hectares (acres) planted	Confidence[1]	
	90%	95%
8 (20)	20	28
16 (40)	31	44
24 (60)	42	60
32 (80)	49	69
49 (120)	52	74
65+ (160)	57	81

[1] Confidence interval = 124 trees/ha (50 trees/acre).

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Provides information on types of containers, use of media, cultural treatments, seed selection, disease and environmental controls, and planting preparation for container grown seedlings.

Keywords: planting guidelines, *Pinus* spp., survival and growth, quality, physiology.

Discussion of chemicals in this paper does not constitute a recommendation for their use or imply that uses discussed here are registered. If herbicides or pesticides are handled, applied, or disposed of improperly, they can harm humans, domestic animals, desirable plants, pollinating insects, and fish or other wildlife. Water supplies can be contaminated. Herbicides and pesticides should be used only when needed and handled with care. Directions on the container label should be followed and precautions heeded.

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Classification and Evaluation of Forest Sites on the Northern Cumberland Plateau

Glendon W. Smalley

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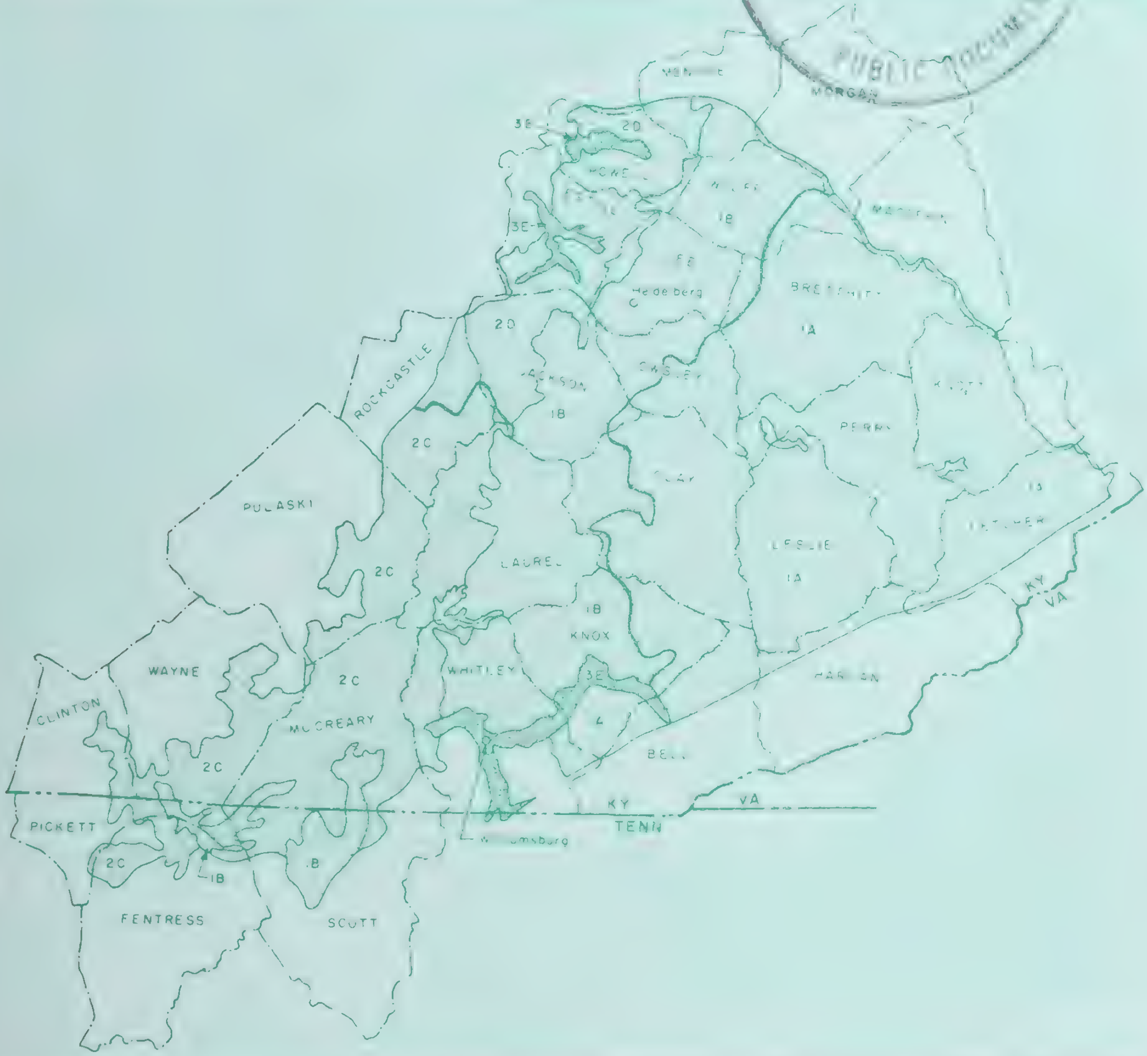

SUMMARY

This paper presents a comprehensive forest site classification system for the northern Cumberland Plateau in north central Tennessee and eastern Kentucky. The system is based on physiography, geology, soils, topography, and vegetation. Twenty-four landtypes are described and evaluated in terms of productivity and desirability of selected pines and hardwoods for timber production. Also, each landtype is rated for five soil-related problems that can affect forest management operations.

ACKNOWLEDGMENTS

I am indebted to my colleagues, past and present, for their scientific input, reviews, and stimulating discussions. I am also grateful to the soil scientists, silviculturists, plant ecologists, and practicing foresters who have reviewed this guide.

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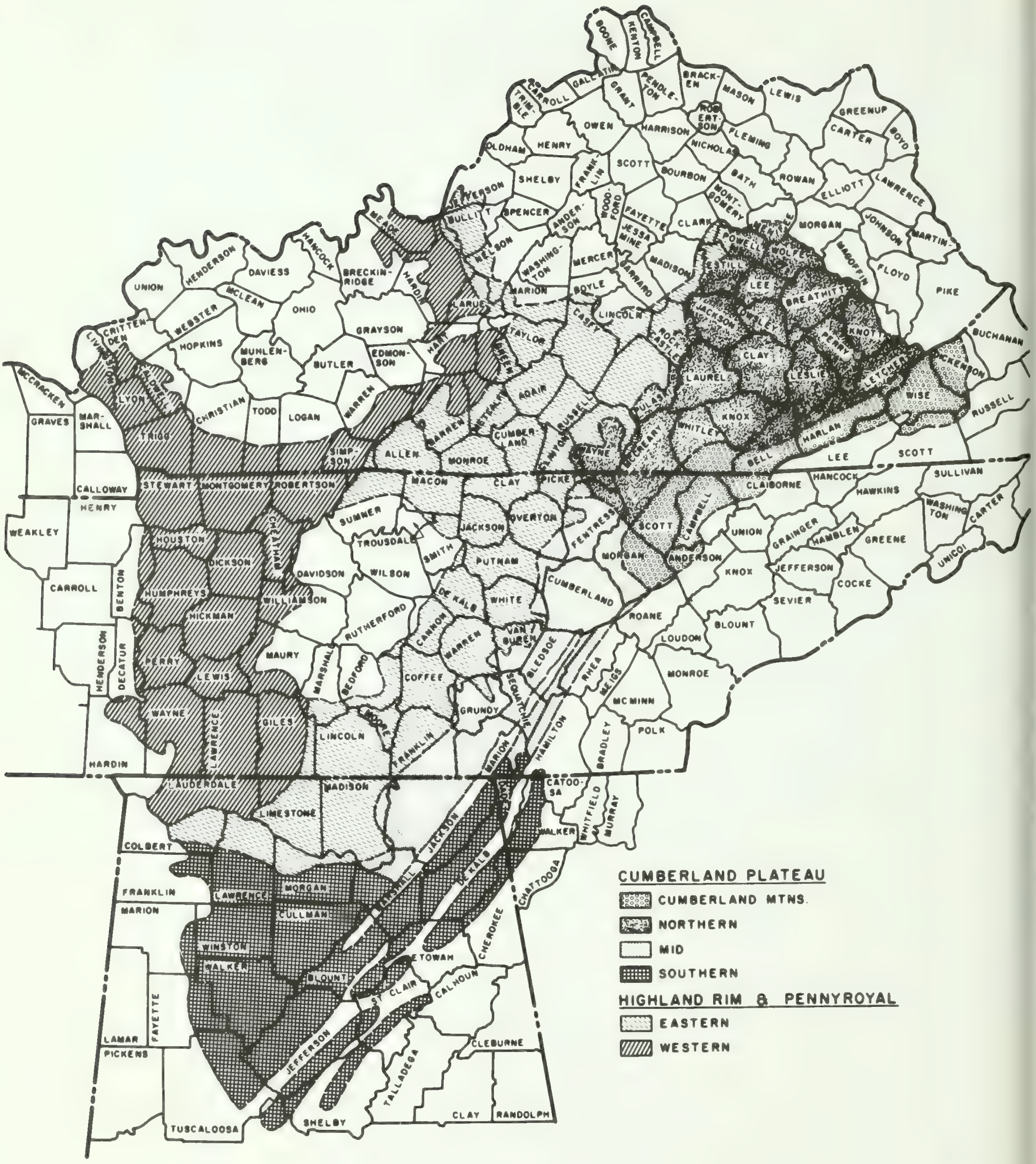

Figure 1.—*Physiographic provinces and regions of the Interior Uplands.*

Classification and Evaluation of Forest Sites on the Northern Cumberland Plateau

Glendon W. Smalley

INTRODUCTION

This report classifies and evaluates forest sites on the Northern Cumberland Plateau (fig. 1) for the management of several commercially valuable tree species. It provides forest managers with a land classification system that will enable them to subdivide forest land into logical segments (landtypes), allow them to rate productivity, and alert them to any limitations and hazards that the landtypes impose on forest management activities. Though soils information is an integral part of this system, users will not need to identify and classify soils or to make laboratory determinations. This report is oriented to timber production because timber is usually a major management objective. However, landtypes can also be the basis for the management and interpretation of other forest resources.

I have drawn freely on much published information on geology, physiography, soils, sites, and yields. In many cases, data specific to this area were not available and information was extrapolated from adjacent regions. Extrapolation was particularly necessary with productivity data. All sources of data are documented, so the user can gauge the accuracy and reliability of the information.

Productivity and management problem information is presented in a format that follows the outline used by the Soil Conservation Service (SCS) in the Woodland Suitability sections of county soil surveys. This similarity should facilitate the integration of information contained in county soil surveys[1] into this classification system.

This guide represents the best information and collective judgment now available. Nevertheless, it is still incomplete. I trust that forest managers, after applying this site classification system, will share their experience with me and make me aware of any shortcomings or needed revisions.

The rationale and methodology of the system and status of reports appeared in the proceedings of the Second Central Hardwood Forest Conference (Smalley 1978), the Forest Soils and Site Quality Workshop (Smalley 1979a), and the 12th Annual Hardwood Symposium (Smalley 1984a). Site classification guides for the Southern Cumberland Plateau, the Western Highland Rim and Pennyroyal, the Mid-Cumberland Plateau, the Eastern Highland Rim and Pennyroyal, and the Cumberland Mountains regions have been published (Smalley 1979b, 1980, 1982, 1983, 1984b).

NORTHERN CUMBERLAND PLATEAU REGION

This region covers about 6,900 mi^2 in all or parts of three counties in Tennessee and 23 in Kentucky. It extends south to north from about north latitude 36°30′ to 37°55′ and east to west from about west longitude 82°35′ to 85°10′. The region extends from south of Oneida in Scott County, TN to the northern watershed boundary of the Kentucky River, including the Red River in Powell, Menifee, and Wolfe Counties, KY, a distance of about 120 mi (fig. 2). North of the Kentucky River watershed the Cumberland Plateau is called the Allegheny Plateau (Fenneman 1938).

Geographically, the Northern Cumberland Plateau consists of the southern two-thirds of the Mountains and Eastern Coalfield region in Kentucky (Bailey and Winsor 1964) plus parts of three northern counties in Tennessee. In Tennessee, it joins the Mid-Cumberland Plateau about on a line from Oneida to Jamestown in Fentress County (Smalley 1982). The Northern Plateau is bounded on the southeast by the Jellico Mountains and Pine Mountain of the Cumberland Mountain region (Smalley 1984b).

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[1] See Appendix for available soil surveys.

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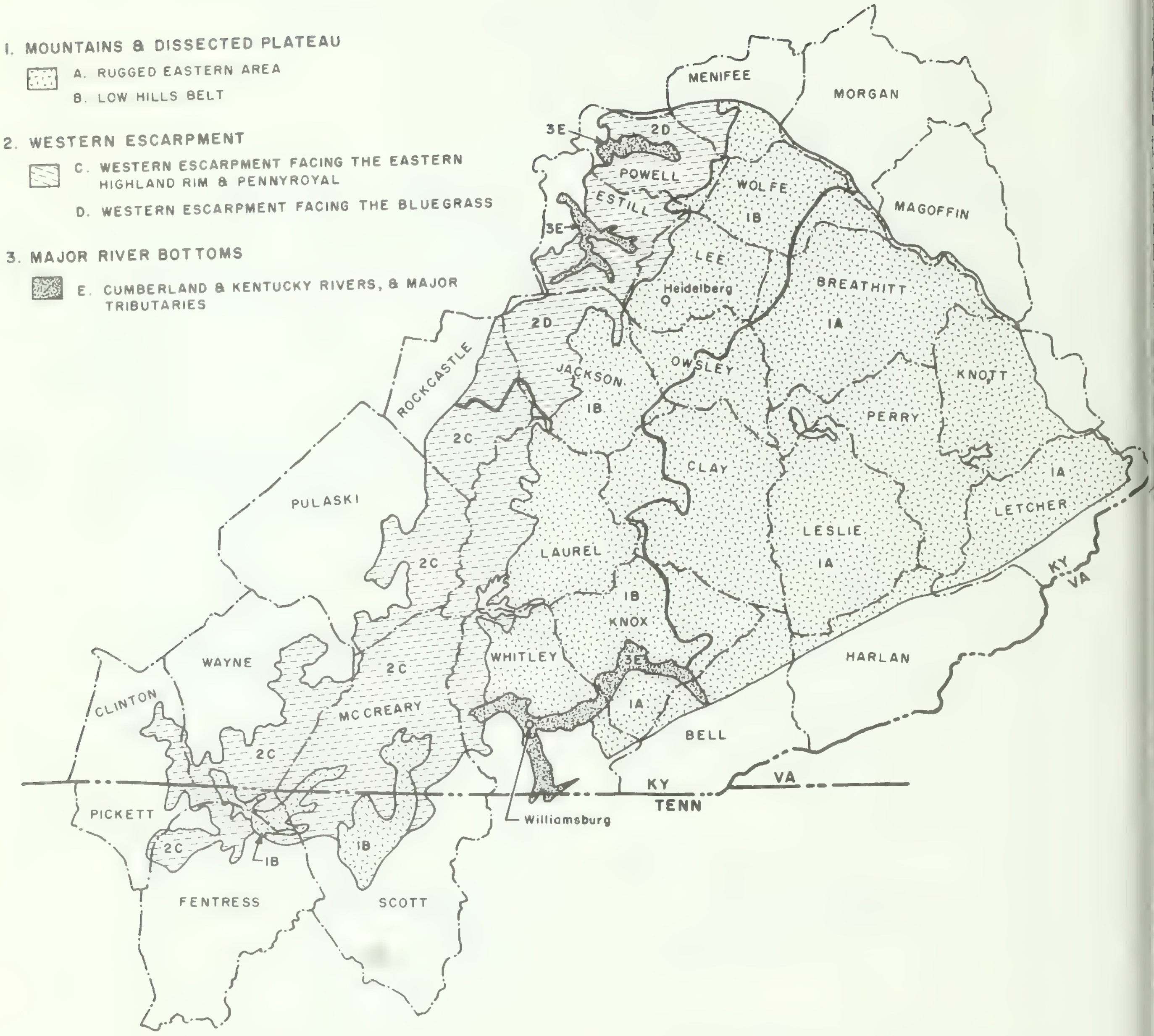

Figure 2.—*Subregions and landtype associations of the Northern Cumberland Plateau region and location of weather stations (Heidelberg and Williamsburg).*

The Northern Cumberland Plateau has three disinct sections. The largest section is the Rugged Eastrn Area (Braun 1950, Bailey and Winsor 1964). It is lso called the Mountain and Creekbottom Area by IcFarlan (1943) and Bladen (1973). West of the ugged Eastern Area is the Low Hills Belt (Braun 950, Bailey and Winsor 1964). The section is called he Cumberland Plateau by Bladen (1973). The westrnmost section is the Western Escarpment (Bailey nd Winsor 1964). Braun (1950) called this area the liff Section, and McFarlan (1943) called it the idgetop and Limestone Valley Settlements Area.

The Western Escarpment has two distinct parts. outh of the junction of the Muldraugh's Hill escarpnent with the Western or Pottsville escarpment in ockcastle County, KY, the Northern Cumberland lateau faces the Eastern Highland Rim and Pennyoyal region (Smalley 1983). North of the junction, the lateau faces the Kentucky Bluegrass region (Feneman 1938, McFarlan 1943). The belt of conical hills nown as the Knobs, between the Bluegrass region nd the Western Escarpment of the Northern Cumerland Plateau, was included in the Eastern Highand Rim and Pennyroyal region (Smalley 1983).

limate

The region has a temperature climate characterized y long moderately hot summers and short mild to ioderately cold winters. According to Thornthwaite's 1948) classification of climate, it is humid mesotheral with adequate precipitation at all seasons. Daily nd seasonal weather are controlled largely by alterating cold, dry continental air masses from Canada nd warm, moist air from the Gulf of Mexico. During ne summer, complete exchanges of air masses are ew, and tropical maritime air masses persist for exended periods. Long periods of mild, sunny weather-ypically occur in the fall. Tables 1 and 2 show averge monthly and annual precipitation and emperature values, average frost-free periods, and levation above sea level for two stations in Kentucky ocated in towns on the Cumberland and Kentucky ivers (fig. 2). Consequently, the data do not indicate limatic conditions in narrow mountain valleys or on igh ridges.

Mean temperature for the region is about 56°F. The date of last freeze is mid- to late April, and the date of first freeze is mid-October. The frost-free period ranges from 180 to 190 days but is probably 10 to 20 days shorter at higher elevations. The temperature often falls below freezing at night in December, January, and February. The upper 6 to 8 in of soils in narrow mountain valleys and on cool slopes may stay frozen much of the winter. Intermittent freezing and thawing occur on south- and west-facing slopes, mountain ridges, and broader ridges, and in hollows at lower elevations. Though air temperature does not appear to vary much across the region, local temperatures vary considerably because of relief, aspect, and cloud cover. In summer, the valleys are very warm and occasionally hot, and the mountains are warm during the day but are cool at night. In winter, the valleys are very cool with occasional cold and warm spells, and upper slopes and mountaintops are generally cold.

Southerly winds prevail from May to September and northerly winds from November to March. Average velocity ranges from 6 to 11 mph but probably exceeds 11 mph on the mountaintops. Severe winds are infrequent and most are associated with late spring and summer thundershowers.

Annual precipitation averages about 46 in and ordinarily is well distributed throughout the year. Seasonal precipitation is greatest in the winter and least in the fall, but the wettest month is July. Short periods of very wet or very dry weather are common. Thunderstorms that commonly occur from March through August are of short duration but often are accompanied by high-intensity rainfall. Steady rainfalls lasting several days sometimes occur in winter and late spring. Those storms are likely to cause local flooding in the mountains because soils are saturated, frozen, or snow-covered. In the winter, precipitation is chiefly rain the valleys and snow, sleet, or freezing rain on the mountaintops. Average annual snowfall is 10 to 16 in, but snow persists for periods longer than a few days only at the highest elevations. Soils are wettest from December through April and driest from July to October. On the average, tree growth is probably retarded for periods of a few days to a week or more several times each growing season. Soil mois-

able 1.—*Average monthly and annual precipitation (in inches) and elevation above mean sea level for two weather stations on the Northern Cumberland Plateau*[1]

Station and county	Years of record	Elevation (ft)	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year
illiamsburg Whitley, KY	89	1,000	4.36	4.28	4.79	4.01	3.95	4.14	5.09	3.62	2.89	2.59	3.76	4.05	47.53
eidelberg Lock 14; Lee, KY	62	663	3.81	3.76	4.57	3.95	3.82	4.27	5.29	3.77	2.87	2.09	3.47	3.42	45.09

.S. Department of Commerce (1976).

Table 2.—*Average monthly and annual temperature (°F) and length of warm period for two weather stations on the Northern Cumberland Plateau*[1]

Station and county	Years of record	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Year	Warm period days[2]
Williamsburg Whitley, KY	80	38	40	47	58	66	73	76	75	69	59	47	39	57	188
Heidelberg Lock 14; Lee, KY	44	36	38	48	57	65	72	76	74	68	58	46	38	56	178[3]

[1] U.S. Department of Commerce (1976).

[2] Mean period from last 32°F to first 32°F (U.S. Department of Agriculture 1941).

[3] Value for Beattyville, Lee County, KY.

ture stress is more common and severe on upper mountain slopes facing south and west, on shallow soils, and on sandy-textured soils.

Geology, Topography, and Soils

The Northern Cumberland Plateau is underlain mostly by Pennsylvanian sandstone, conglomerate, siltstone, shale, and coal belonging to the Crab Orchard and Crooked Fork groups in Tennessee (Swingle and others 1966) and the Lee and Breathitt formations in Kentucky (McDowell and others 1981). In Tennessee, the Rockcastle member of the Crab Orchard group is most extensive, while the Breathitt is most extensive in Kentucky. Generally, these sedimentary strata dip gently to the southeast but become nearly level in the Rugged Eastern area.

North of the junction with the Muldraugh's Hill escarpment in Rockcastle County, KY, the Western Escarpment lies east of the traditional margin of the Plateau. The Western Escarpment lacks the prominence of farther south because of the thinning of the Rockcastle sandstone and the pronounced southeasterly dip of strata away from the Cincinnati Arch centered under the Kentucky Bluegrass region (see Braun 1950, p. 89). Here the Western Escarpment is a transition zone consisting of narrow ridges and hills capped with Lower Pennsylvanian sandstone and underlain by mid- and upper Mississippian rocks.

South of the junction, the Western Escarpment is fairly thick, nearly continuous, and very ragged. Below the Rockcastle sandstone escarpment the scarp slope cuts across nearly horizontal strata of Mississippian limestone, dolomite, sandstone, and shale. In places, the slope is smooth, but in other places, the slope is interrupted with benches supported by more resistant Mississippian rocks.

Alluvial deposits of Quaternary age occur along the Cumberland, Kentucky, and Red Rivers and some of the major tributaries (McDowell and others 1981).

Regional topography ranges from gentle in parts of the Low Hills Belt to rugged and complex in the Rugged Eastern Area and the Western Escarpment. Slope varies from nearly level to very steep.

The maturely dissected Rugged Eastern Area is characterized by narrow winding ridgetops, steep sideslopes, and narrow winding valleys. Some of the roughest land in the Eastern United States is in the upper basin of the Kentucky River. Elevation gradually increases toward the southeast where some mountain crests near Pine Mountain are about 2,000 ft above mean sea level. Relief is 500 to 700 ft in the western part and increases to about 900 to 1,000 ft in the eastern part. There is little flat land except on a few broader ridges and in river and creek bottoms. Sideslopes are often benched, reflecting the presence of thin, more resistant layers of sandstone sandwiched between thick layers of shale.

The Low Hills Belt, characterized by submature dissection and undulating topography, is the smoothest part of the Northern Plateau. The belt, about 25 mi wide, extends from Whitley and Knox Counties northward to Wolfe County. Valleys vary in width and are moist, even swampy in places. Larger streams and rivers have cut moderately deep gorges in the Plateau surface that are rimmed with discontinuous sandstone cliffs. Slopes below the cliffs are steep and strewn with rocks. Relief is only 100 to 150 ft in the undulating parts but is 300 ft or more in the vicinity of gorges. Elevation ranges from 1,300 to 1,500 ft in the north and decreases gradually to 1,100 to 1,200 ft in the south.

The Western Escarpment Area is maturely dissected, more so in the northern part than in the southern part because of a more pronounced dip of the rocks and exposure of less resistant carbonate rocks farther north. The area is characterized by long, narrow to moderately broad ridgetops, steep sideslopes, and narrow to moderately broad valleys. Some gently rolling to rolling broad ridges occur in southern Kentucky nd northern Tennessee. The average elevation of the lateau surface is about 1,400 ft in the vicinity of the entucky and Red Rivers and rises to 1,800 to 2,000 t in southern Kentucky and northern Tennessee. Re- ief averages 200 ft in the vicinity of small creeks and treams but increases to 600 to 800 ft near larger treams and rivers.

Streams are entrenched in steep-sided valleys hose walls are often capped with sandstone cliffs. verhanging rock shelters and natural bridges are requent. Rapids and waterfalls are typical in free- owing creeks and streams. These features are well isplayed in the Red River Gorge and along the South ork of the Cumberland River.

The northern part of the Western Escarpment has ong, narrow, convex ridgetops and long, narrow treambottoms that gradually widen westward. ideslopes are divided by a nearly continuous lime- tone escarpment higher on the slope from east to est. Local relief is from 400 to 600 ft.

In the southern part, sideslopes are broken with early continuous sandstone cliffs, but limestone rops out on lower slopes and on convex spur ridges xtending out into the Highland Rim and Pennyroyal.

The Northern Plateau is drained by the Cumber- and and Kentucky River systems (McDowell and oth- rs 1981, Swingle and others 1966, Bladen 1973). The umberland River breaches Pine Mountain at ineville, KY, in a narrow watergap at an elevation of bout 1,000 ft, then turns northeastward and follows he backslope of Pine Mountain for nearly 60 mi Smalley 1984b). Lake Cumberland, formed behind Volfe Creek Dam, has a normal level of 723 ft and xtends nearly to Cumberland Falls State Park and a hort distance up the Rockcastle River. Laurel River ake, west of Corbin, was built by the U.S. Army orps of Engineers for flood control and recreation. outh Fork, another tributary, originates on the umberland Plateau in northern Tennessee; it has een designated a Wild and Scenic River.

The Kentucky River used to be the only navigable ver that crossed the Western Escarpment of the lateau. Barge traffic was possible to Beattyville in ee County, where the main river branched into three rks. In 1983, commercial use of the river was sus- ended upstream from Frankfort in Franklin County. he North Fork originates 168 mi upstream near the irginia state line. The Middle Fork originates 97 mi pstream in Leslie County. Buckhorn Lake, on the iddle Fork west of Hazard, is a 1,200-acre manmade ke that furnishes flood control and recreation. The outh Fork originates 75 mi upstream at the conflu- nce of Goose Creek and the Red Bird River.

The Red River Gorge, in Menifee and Powell Coun- es, is a scenic geological area on the Daniel Boone ational Forest. Westward, the Red River flows hrough the Knobs region in a moderately wide valley before joining the Kentucky River northeast of Richmond.

Most of these rivers and streams flow in deep, fairly narrow valleys on the Plateau, except in the uppermost reaches where stream profiles are broad V-shaped to U-shaped. Many towns, including several county seats, are located on the flood plains, with built-up areas extending up nearby slopes. Flooding of flood plains is frequent; extent and severity of damage increase downstream.

Soils have formed from material weathered from a variety of sedimentary rocks. Generally, these soils are pale, loamy to clayey, friable, and low in fertility, and vary in content of rock fragments. The more extensive soils are classified as loamy or clayey, mixed or siliceous, mesic Dystrochrepts and Hapludults. Some Hapludalfs occur in the northern part of the Western Escarpment. Soils forming in spoil material from surface mining of coal are classified as Udorthents.

In the Rugged Eastern Area, soils on upper mountain slopes and ridges formed in material weathered from shale or sandstone, depending on elevation. Probably two-thirds or more of the soils are colluvial. On some slopes, colluvium extends three-fourths or more of the way to the mountain crests. On some mountain slopes, a series of narrow benches and short cliffs form a stairstep pattern. Soils on ridgecrests are 2 to 4 ft deep; soils on steep, convex upper slopes and points of ridges are 1 to 3 ft deep; and soils on colluvial slopes are 5 to 15 ft deep. In coves and on cool slopes at higher elevations, soils have dark surface horizons. In the Rugged Eastern Area, soils are mostly well-drained and are generally somewhat heavier textured than soils common to the smoother part of the Low Hills Belt and the Western Escarpment. Shale-derived soils are about as clayey as those formed over Mississippian limestone, shale, and siltstone in the northern part of the Western Escarpment.

In the Low Hills Belt, soils on gently sloping to sloping broader ridges and short smooth slopes are moderately deep to deep and well-drained; they formed in material weathered mostly from sandstone and conglomerate. Loamy colluvial soils have developed on long, strongly sloping to steep sideslopes. Also, colluvial soils occur on steep, rocky slopes below sandstone cliffs in gorges along major creeks and streams.

In the southern section of the Western Escarpment Area, soils on narrow ridges and hills above the sandstone cliffs are typically moderately deep and well-drained with loamy subsoils. Colluvial soils that occur on steep upper scarp slopes are loamy, deep, and well-drained. On lower scarp slopes, colluvial soils are bisequal with subsoil horizons forming in material weathered from the underlying Mississippian limestone, and soils on toeslopes formed almost entirely in limestone material.

In the northern section of the Western Escarpment Area, soils on narrow ridges and hills formed in material weathered from thin sandstone and conglomerate caprock. Below the relatively short sandstone cliffs, on some spur ridges, and on the associated steep sideslopes, soils formed in residuum or colluvium weathered from Mississippian limestone, shale, siltstone, and sandstone.

Moderately extensive deep, well-drained to poorly drained, mostly loamy alluvial soils occur on flood plains and terraces along the Cumberland and Kentucky Rivers and major tributaries. Farther upstream, bottom soils are deep, moderately well-drained to well-drained, and loamy. Generally, alluvial soils are moderately fertile and well-suited to agriculture, but seasonal wetness limits their use.

Common residual upland soils are Alticrest, Berks, Dekalb, Gilpin, Latham, Lily, Muskingum, and Ramsey. Common colluvial soils are Brookside, Cranston, Cutshin, Grimsley, Jefferson, Rigley, Shelocta, and Zenith. Common alluvial soils are Atkins, Bonnie, Clifty, Combs, Cuba, Ealy, Grigsby, Philo, Pope, Sewanee, Stendal, and Stokly.

There is little smooth land in the Northern Cumberland Mountain Region, and most of it is used for agriculture or building sites. Forests occupy 48 to 95 percent of Northern Cumberland Plateau counties. Seventeen of the 26 counties are more than three-fourths forested (Staff, Renewable Resources Evaluation Research Work Unit 1982, Kingsley and Powell 1978). Counties having the lowest percentages of forest land lie in the Highland Rim-Pennyroyal physiographic province as well as the Cumberland Plateau. Large tracts are owned by lumber and coal companies. All of five ranger districts and part of another district of the Daniel Boone National Forest lie in the Northern Cumberland Plateau Region.

Considerable land has been disturbed by surface mining for coal and drilling for natural gas and oil. Federal regulations now require the rehabilitation of surface-mined land and drilling sites. Some reclaimed land is being used for shopping centers, schools, athletic fields, airports, and subdivisions. Those uses depend on easy accessibility and/or proximity to existing developed areas. The potential for using reclaimed land for improved pasture and forests is high, but is currently not being realized. Most land disturbed before passage of reclamation laws gradually reverts to forest, but soil erosion, stream sedimentation, and surface- and ground-water pollution will be serious problems for many years. Bryan and Hewlett (1981) found that average storm flows from six small watersheds in Breathitt County, KY, were not changed by surface mining, whereas average peak flows increased 36 percent, but only in the summer. Small peak flows doubled, moderate flows increased about one-third, peak flows of about 100 csm were largely unaffected, and larger peak flows may have been reduced by surface mining. The maximum annual storm flows, usually occurring in winter or spring, were slightly reduced. No time trend in either storm flows or peak flows was detected. They concluded that surface mining was not a serious floodwater discharge problem.

Gradient, aspect, slope length, and soil moisture are important factors in the delineation of landtypes described later. Slope steepness, soil thickness, and topographic position affect the rate and amount of both surface runoff and subsurface movement of soil water. Soil loss by erosion increases as gradient and length of slope increase. Although surface runoff and soil erosion are rare under forested conditions, they are important factors during road construction, logging, and other forest management operations. Slumping of the soil mass is fairly common on some undisturbed steep slopes and is exacerbated by road construction. Soils on short, steep slopes are often shallower than soils on more nearly level terrain, while those on long steep slopes are often very deep. Deposition of sediments on gently terrain by surface runoff is greatest below the longer and steeper slopes.

Generally, the steeper the gradient and the longer the slope, the greater the subsurface flow of soil water downslope. As a consequence, plants on lower slopes grow for longer periods without moisture stress. Subsurface flow may result in excessively wet soils having poor aeration at the base of slopes, especially those underlain by shale.

Aspect affects air and soil temperatures by altering insolation. Generally, soil temperatures are lower on north-facing than on south-facing slopes. Because soils on north-facing slopes tend to retain moisture for longer periods during the growing season, rate of tree growth is faster, and species composition is richer. Franzmeier and others (1969) in a study of soil properties on steep north- and south-facing slopes of the Northern Cumberland Plateau in McCreary County, KY. found that, at a depth of 20 in, lower slopes were cooler than mid- and upper slopes. Lower slopes were shaded in the morning and evening by adjacent mountains in this steep, highly dissected landscape. Also, lower slopes tended to be more moist than upper slopes because of internal moisture flow. These moister soils warm more slowly because of the relatively high specific heat of water and shorter periods of time they are exposed to direct sunlight.

However, Lee and Sypolt (1974) suggested that in areas of high summer precipitation, such as the Northern Cumberland Plateau, marked differences in tree growth are not associated with soil moisture differences. During midday on south-facing slopes, it appears that (1) super-optimum temperatures for net assimilation frequently occur in forest canopies, (2) lower soil temperatures limit the absorption of

ailable water, and (3) higher canopy temperatures
crease the transpiration demand, create leaf water
ficits earlier in the day, and magnify the midday
pression of net assimilation.

Shading by an adjacent landmass is an important
e factor in highly dissected landscapes. Although
tempts to quantify the effects of shading generally
ve been unsuccessful, the effects are evident both in
rest stand composition and tree growth rates. Shad-
g effects are now being recognized by soil surveyors,
g., in the soil survey of Leslie and Perry Counties,
Y (Hayes 1982), the Shelocta-Cutshin association,
nsisting of deep, well-drained soils on northerly
ountain slopes, in coves, and on benches was ex-
nded 10 to 15 percent up the opposing southerly
opes before changing to a Shelocta-Gilpin
sociation.

In *Soil Taxonomy*, temperature regime is one of
veral differentiae used to group soils within a sub-
oup having similar physical and chemical proper-
s (Soil Survey Staff 1975). On the Northern Cum-
rland Plateau, nearly all soils are classed as mesic,
t a few are thermic. The temperature regime of
esic soils ranges from 8° to 15°C (47° to 59°F), and
e regime of thermic soils ranges from 15° to 22°C
9° to 72°F). Both classes also have a difference of 5°C
F) or more between mean summer and mean win-
soil temperature. All temperature measurements
e at a depth of 50 cm or at a lithic or paralithic
ntact, whichever is shallower. In the descriptions of
ndtypes that follow, both mesic and thermic soils
e listed as occurring on a few landtypes to conform
current SCS classification. Soils differing only in
nperature regime seem to have similar tree growth
tential and management problem interpretations.
wever, average annual soil temperature does not
lect the daily and seasonal fluctuations, particu-
ly in the top few inches. These fluctuations proba-
influence tree growth more than average
nperature.

t is commonly thought that soils on steep mountain
pes have thin, weakly developed sola over bedrock.
ls developed from acid sandstones, siltstones, and
les on the Northern Cumberland Plateau have
p, well-developed sola and appear relatively stable
pite fairly steep slopes (Franzmeier and others
9). Soils on midslopes contain more rock frag-
nts than those on upper or lower slopes. Soils on
er slopes have higher base status. Most soils on
th slopes have argillic horizons, whereas most soils
north slopes have cambic horizons. Soils on north
bes have almost 2°C lower mean annual tempera-
e, contain more organic matter, are darker in color,
hold more water during periods of water stress
n soils on south slopes.

ailey and Avers (1971) studied colluvial soils on
bes east and west of the Pottsville escarpment in
Kentucky. East of the escarpment, Pennsylvanian-age rocks of the Breathitt or Lee formations underlie relatively short, smooth, concave slopes that average 34 percent in gradient. West of the escarpment, Mississippian-age rocks of the New Providence Formation underlie relatively long, smooth, convex slopes that average 48 percent in gradient. White oak, pignut and mockernut hickories, and scarlet oak dominated both areas. East of the escarpment, yellow-poplar, blackgum, and Virginia and shortleaf pines were common associates. Slopes west of the escarpment had more scarlet oak, and common associates were chestnut oak and sassafras.

Soils over Pennsylvanian rocks were classified in the Shelocta series (fine-loamy, mixed, mesic Typic Hapludult), and those over Mississippian rocks were classified in the Cranston series (coarse-loamy, mixed, mesic Typic Hapludalf). Cranston soils have since been reclassified into the ultic subgroup of Hapludalfs. Cranston soils have coarser texture, higher pH, and higher percentage of base saturation, and they provide significantly better forest growth conditions than Shelocta soils. On northeast slopes, yellow-poplar and oaks grew better on Cranston soils than on Shelocta soils, and oaks grew at about the same rate on southwest slopes on both soils. On Cranston soils, site index of oaks varied by 14 ft between cool and warm aspects; on Shelocta soils, oak site index varied by only 7 ft between cool and warm aspects.

Vegetation

The late Dr. E. Lucy Braun conducted extensive vegetation studies on the Cumberland Plateau and Cumberland Mountains in the 1930's and 1940's. This research formed the basis for her concepts of deciduous forest development and succession, which were synthesized in her book *Deciduous Forests of Eastern North America* (Braun 1950). This volume remains the only authoritative description of the eastern deciduous forest.

The centrum of Braun's mixed mesophytic forest region is in the Cumberland Mountains (Smalley 1984b), southeast of the Northern Cumberland Plateau. However, the mixed mesophytic forest occurs throughout the Cumberland and Allegheny Plateaus in Tennessee and Kentucky. Northeastward on the Allegheny Plateau the mixed mesophytic forest changes gradually to northern forest types dominated by American beech, sugar maple, eastern hemlock, and eastern white pine. Southward on the Cumberland Plateau oaks become more common, and yellow pines dominate certain topographic situations. The true mixed mesophytic communities are confined to cool valley slopes (Smalley 1979b, 1982).

In Braun's mixed mesophytic forest, the dominant climax species of American beech, yellow-poplar, white basswood, sugar maple, American chestnut, yellow buckeye, northern red oak, white oak, and eastern hemlock were not universally present. Physiographic climaxes were numerous and added to the diversity of the region. Other locally important species were yellow birch, river birch, black cherry, cucumbertree, white ash, red maple, blackgum, black walnut, shagbark hickory, and bitternut hickory. Composition and relative abundance varied greatly from place to place because of the large number of dominants in the climax. A dozen or more additional tree species seldom or never attained canopy position. The shrub and herbaceous vegetation was rich and varied.

Recently, Ware (1982) clarified, by a Bray-Curtis polar ordination, the distributional relationships among species in the Cumberland Mountains. Yellow buckeye, white basswood, and sugar maple were concentrated in stands at the opposite end of the vegetational gradient from eastern hemlock and white oak. The distribution of yellow-poplar overlapped that of all five of these species. American beech was important all across the ordination except in stands containing a high proportion of white basswood and yellow buckeye. The ordination supported Braun's treatment of the mixed mesophytic forest as a single integrating complex rather than several remotely related forest communities.

Braun (1950) described the primary forest of the Rugged Eastern Area of Kentucky as a mosaic of climax and subclimax communities. Diversity of topography, soils, and micro-climate was largely responsible for the complexity of the forests. Generally, the mixed mesophytic forest occurred on slopes, with white basswood most conspicuous on cool slopes and American beech proportionately more on warm slopes. Also, oaks, particularly white oak, were conspicuous on warm slopes. Eastern hemlock occurred in some ravines and was usually accompanied by rhododendron. Umbrella magnolia was conspicuous in ravines, whereas bigleaf magnolia was sometimes dominant in second-growth stands. On soils formed mostly from sandstone, pitch pine and shortleaf and/or Virginia pine were dominant. On ridgetops and upper slopes, mixed oak and oak-hickory communities were common. Chestnut, white and black, were the most common oaks, while post oak was prevalent on the driest sites. In saddles of ridges, the mixed mesophytic forest communities mingled with mixed oak and oak-hickory communities.

In the Low Hills Belt, the mixed mesophytic forest was not as extensive as in the Rugged Eastern Area or the Western Escarpment. In this topographically subdued area, mid- and lower slopes supported a white oak-American beech community that changed to mixed oaks or oak-hickory on upper slopes and ridges. Broad, saucer-shaped valleys, typical of streamheads, were moist or even swampy. These streambottom forests were composed mostly of red maple, sweetgum pin oak, blackgum, and swamp white oak; patches o alder were common. In less-wet areas, white oak an American beech were common. River birch was com mon along the banks of larger streams and rivers. A the streams flow westward, they become entrenche into strata of lower Pennsylvanian age. The mixe mesophytic forest occupied these coves and ravin slopes.

In the Western Escarpment, margins above th sandstone cliffs were dominated by pines, mountain laurel, vacciniums, and other heath shrubs. Scarle and chestnut oaks were often mixed with the pines. I places, open pine stands supported extensive gras cover. Slopes, except those that had been cleare were occupied by mixed mesophytic communitie Eastern hemlock was dominant in the narrow gorge and on north-facing talus slopes below the sandston cliffs. Here rhododendron formed impenetrable thick ets. Umbrella, bigleaf, and Fraser magnolias, an American holly were also common understory specie As the gorges widen and the streams emerged from between the bordering cliffs, American beech dom nated the sloping terraces and valley floors. Whit oak and American beech were most abundant o southerly slopes, while more typical mixed mes phytic communities were on cool slopes. Chinkapi oak occurred on calcareous soils formed from pare material of Mississippian origin. Occasionally, eas ern white pine occurred with eastern hemlock in th gorges.

Existing forests bear little or no resemblance those that Braun described 40 to 50 years ago. Ame ican chestnut is gone, and extensive logging, co mining, and wildfire have all caused drastic chang in tree size and composition of Northern Cumberlan Plateau forests. Also, the absence or reduction in o currence of wildfire since organized fire protection b gan has altered forest composition and succession pa terns. Selectively logged stands have simil composition and frequencies of occurrence but la the large trees seen in photos illustrating Braun book (1950, chapter 4). The species composition most second-growth stands originating after comme cial clearcutting is similar to the composition of th original stands, but frequencies of occurrence diff considerably. A few scattered old-growth remnants the mixed mesophytic forest remain.

Martin (1975) described the largest protected re nant, the Lilley Cornett Woods, in Letcher County the Rugged Eastern Area of Kentucky about 5 northwest of Pine Mountain, the northwest bounda of the Cumberland Mountains Region (Smalley 198 This old-growth forest is registered as a Nation Landmark with the U.S. Department of Interior a as a Natural Area with the Society of Americ oresters. A sugar maple—white basswood—yellow-oplar community occurs on the cool colluvial slopes f a large east-facing cove but occupies less than 0 percent of the old-growth area. The major species n the community are recognized mesophytes. Eastrn hemlock occurs throughout the forest but domiates only about 5 percent of the area.

Nearly 50 percent of the old-growth forest is occuied with communities dominated by American beech n association with yellow buckeye, sugar maple, and hite oak. Chestnut oak, white oak, and other mixed ak communities are common on warm slopes, ridgeops, and upper convex slopes on all aspects. These ak communities occur on about 35 percent of the rea.

This old-growth mixed mesophytic forest is continuusly disturbed by scattered tree falls (Romme and Iartin 1982). Nearly half of the gaps in the dominant anopy were caused by uprooting or stem breakage of merican beech. The largest number of gaps were ormed in the summer months. Tree fall was unreated to regional weather patterns but was strongly nfluenced by local windstorms of high velocity and hort duration. This disturbance pattern suggests a shifting mosaic steady-state" model of forest developent. Based on a short period of monitoring, the averge life expectancy of dominant trees was estimated o be 269 years.

Another remnant of the mixed mesophytic forest is n Rock Creek Gorge, Laurel County, KY, and repreents the Western Escarpment of the Northern Cumerland Plateau region (Winstead and Nicely 1976). he gorge has been designated a natural area. The orge, bounded by a sandstone cliff, averages about 60 ft deep and 0.25 mi wide. It extends about 1.2 mi om the head of the gorge to the confluence with the ockcastle River. Eighty-two percent of the total and basal area of 207 ft^2 ac^{-1} is dominated by eastn hemlock, yellow-poplar, sweet birch, and red aple. Minor species are northern red oak, American olly, blackgum, black cherry, American beech, white ak, bigleaf magnolia, American hornbeam, and flowing dogwood. Several of the largest eastern hemcks were 30 in d.b.h. and larger; several yellow-oplars exceeded 40 in d.b.h.

Muller (1982, 1983) compared an old-growth porton of the Lilley Cornett Woods (Big Everidge Holw) with an adjacent 35-year-old second-growth frest (Pollbranch Hollow). Basal area of trees ≥4 in d.b.h. was 121 ft^2 ac^{-1} in the old-growth hollow and [illegible]7 ft^2 ac^{-1} in the second-growth hollow. There were more white oak, sugar maple, American beech, and white ash trees in the old-growth forest than in the second-growth forest but more northern red oak and yllow-poplar in the second growth than in the old gowth. Only white oak and white ash had significantly more basal area in the old growth than in the second growth. Basal area of non-commercial species—black locust, sassafras, eastern redbud, and flowering dogwood—in the second growth was nearly double that in the old growth, suggesting that some form of timber stand improvement might substantially increase the composition and growth of commercial species. The second-growth forest has not exhibited a strong species shift. The diameter distribution of both the old-growth and second-growth forests was described very well by inverse J-shaped functions.

Herman and See (1973) reported on succession following a seemingly moderately hot wildfire in Tight Hollow, an old-growth mesic forest located on a tributary of the Middle Fork of the Red River. Tight Hollow is typical of headwater areas in the Low Hills section of the Northern Cumberland Plateau. The hollow is ringed with a sandstone cliff, and local relief is about 240 ft. Forty-seven years after the fire, the overstory in the burned area consists of yellow-poplar and overmature eastern hemlock that survived the fire. Yellow-poplar comprises 71 percent of the stand basal area. Minor overstory species are bigleaf magnolia, umbrella magnolia, sweet birch, and red maple. Major understory species are eastern hemlock, rhododendron, sweet birch, yellow-poplar, and red maple. The unburned part of the hollow supports an eastern hemlock—yellow-poplar community, with extensive windthrow of the hemlock. Rhododendron, flowering dogwood, and umbrella and bigleaf magnolias dominate the understory.

Fifty years after being commercially clearcut and subjected to frequent wildfires, streambottoms and north slopes in the Rugged Eastern Area were dominated by yellow-poplar and contained a lush understory of American hornbeam, cucumbertree, bigleaf magnolia, umbrella magnolia, and American beech (Carpenter 1976). South-facing slopes were dominated by white oak, American beech, northern red oak, and hickories. Only 10 of 25 major woody species were common to all three sites—sugar maple, sweet birch, American hornbeam, American beech, white ash, yellow-poplar, bigleaf magnolia, cucumbertree, umbrella magnolia, and sassafras. Slippery elm, American sycamore, and red mulberry occurred only in the streambottoms, whereas pignut hickory, shagbark hickory, mockernut hickory, and northern red oak occurred only on south slopes. American basswood was the only species restricted to north slopes. Despite strong differences in soils and microclimate, black walnut, sourwood, red maple, blackgum, and white oak occurred on south slopes and in streambottoms. Only eastern hemlock was restricted to north slopes and streambottoms. Basal area per acre of all trees taller than 4.5 ft was 185 ft^2 in streambottoms, 140 ft^2 on north slopes, and 137 ft^2 on south slopes.

Fedders (1983) studied the vegetation of the 320-acre Spencer-Morton Preserve in Powell County, KY.

The highest ridges were about 1,400 ft in elevation and were capped with Pennsylvanian sandstones and conglomerates, whereas slopes were underlain with Mississippian siltstone, shale, and fine-grained sandstone. The soils of the Preserve were common to the Cumberland Plateau, indicating that the Preserve should be assigned to the western escarpment section of the northern Plateau and not to the Knobs region of the Eastern Highland Rim and Pennyroyal (see LTA-H in Smalley 1983). Although Braun (1950) asserted that mixed mesophytic forests once occupied many of the slopes in this area, there was no indication from the current oak and hickory communities that mixed mesophytic forests were present in the Preserve in presettlement time. Chestnut oak, pignut hickory, white oak, black oak, and mockernut hickory were the dominant overstory species, and sassafras, red maple, and flowering dogwood were the dominant understory species. The typical dominants of mixed mesophytic forests—American beech, white basswood, yellow buckeye, and sugar maple—were virtually absent. The substantial presence of oaks and hickories in the understory suggests a stable species composition in the future.

Safley (1970) described the vegetation of the gorges, the submaturely dissected plateau top, and a small portion of the adjacent Jellico Mountains in the watershed of the South Fork of the Cumberland River in southern Kentucky and northern Tennessee. Twenty-two forest types were identified—white oak was dominant in 15, chestnut oak was dominant in 5, and northern red oak was dominant in 2. Eastern redcedar, Virginia pine, and shortleaf pine were dominant in eight forest types, but in only two—eastern redcedar and Virginia pine-eastern white pine—were conifers the sole dominants. Eastern hemlock occurred in 13 forest types but was dominant in only 2. American beech was dominant in only three forest types. Mixed mesophytic forest types were restricted to the most protected sites. Overall, vegetation was intermediate in composition between the Mixed Mesophytic Forest region and oak-hickory types of the Western Mesophytic Forest region. Dominance of white oak is characteristic of the Cliff Section of the Mixed Mesophytic Forest region.

These studies sought to identify and classify existing old-growth and second-growth forest communities. Other investigators have attempted to relate the growth of selected commercially valuable tree species to soil properties and topographic factors.

Byrne and others (1965) studied the relation of forest composition and stand structure to the occurrence of Dekalb and Wellston soils on narrow, gently sloping ridgetops in McCreary County, KY. Dekalb soils were dominated by shortleaf pine, with lesser frequencies of Virginia pine, oaks, and mockernut hickory. Wellston soils were dominated by scarlet, white, chestnut, and black oaks, with lesser frequencies of shortleaf pine, Virginia pine, and pignut hickory. On Dekalb soils, shortleaf pine had a mean site index (base age 50 years) of 61±7 ft, and on Wellston soils, it had a mean site index of 70±5 ft. They concluded that inherent differences in soil texture and thickness probably resulted in different rates of natural succession, variation in species adaptability, and relative site potential. These inherent differences have direct application for forest management planning.

Hutchins and others (1976) found that soils, microclimate, and vegetation differed greatly between exposed northeast- and southwest-facing slopes in the Rugged Eastern Area of Kentucky near Hazard. Fine-loamy Shelocta soils had developed on northeast slopes, and coarse-loamy Rigley soils had develope on southwest slopes. Air temperature, throughfall soil temperature, and annual fluctuation of soil temperature were all significantly greater on southwes than on northeast slopes. There were more species o trees >4 in d.b.h. on northeast slopes, and thes tended to be the more mesophytic ones, includin yellow-poplar, American basswood, and cucumbertree. On southwest slopes, plant communities wer less diverse and were composed mostly of oaks an hickories. Stands on northeast slopes had highe basal areas than those on southwest slopes.

In the Rugged Eastern Area, Honeycutt and other (1982) found that the height growth of white oak wa significantly related to tree age, nitrogen content o the A horizon, aspect, slope position, and thickness o the B horizon. The ranking of site index among soil was Shelocta > Wernock loam variant > Rigley, bu only the difference in site index between Shelocta an Rigley soils was statistically significant. The rankin among sites was lower slopes > broad ridges > mid slopes, and differences between all pairs were statisti cally significant. No mean site indices were reporte for either soils or sites.

Also in the Rugged Eastern Area, Eigel and other (1982) found that the height growth of yellow-popla was significantly related to tree age, organic matte content of the A horizon, thickness of the A horizo stand basal area, thickness of the solum, and pH of th A horizon. The ranking of site index among soils wa Cutshin (102) > Shelocta (99) > Pope (96) > Gilpi (91), and among sites was coves (107) > sideslope (99) > streambottoms (96). No statistics were given t indicate which, if any, of the differences between pai in either group was significant. No comparisons wer made between site indices in either of these tw studies and those published by SCS for specific soil

Besides describing the vegetation of the Spence Morton Preserve, Fedders (1983) found that specie occurrence, frequency, and basal areas were signif cantly related to several soil and site variables, bu only a small amount of variation was explained by th best multiple regressions.

The effort by SCS to determine mean site indices of selected tree species by soil series and the few studies mentioned above are the only attempts to determine relative or absolute productivity of Northern Cumberland Plateau forest sites other than on a regional basis (Staff of Renewable Resources Evaluation Research Work Unit 1982, Kingsley and Powell 1978).

SUBREGIONS AND LANDTYPE ASSOCIATIONS

I divided the Northern Cumberland Plateau Region into three subregions: (1) mountains and dissected plateau, (2) Western Escarpment, and (3) major river bottoms (fig. 2). Minor river bottoms and streambottoms are included in Subregions 1 and 2. Subregions 2 and 3 were divided into two landtype associations (LTA's) each, whereas Subregion 3 has only one landtype association. Landtype associations correspond closely to soil associations on general soil maps for Tennessee and Kentucky (Soil Conservation Service 1975, Springer and Elder 1980) (table 3). A description of these landtype associations follows.

Subregion 1: Mountains and Dissected Plateau

Landtype Association-A: Rugged Eastern Area.—This LTA bears the name assigned to the area by Braun (1950) and coincides with the more mountainous eastern area of Bailey and Winsor (1964). It corresponds to the eastern part of soil association G-3 (Jefferson-Shelocta-Steinsburg) in Kentucky. Also included is a portion of soil association G-2 (Latham-Shelocta) south of the Cumberland River in eastern Whitley and southern Knox Counties, KY. This portion of soil association G-2 borders on the Cumberland Mountain Region (Smalley 1984). Topographically, it is too rugged to be included in soil association G-2, an area of more subdued relief assigned to LTA-B.

Table 3.—*Subregions and landtype associations of the Northern Cumberland Plateau region*

Subregion	Landtype association
Mountains and dissected plateau	A. Rugged Eastern Area
	B. Low Hills Belt
Western Escarpment	C. Western escarpment facing the Eastern Highland Rim and Pennyroyal
	D. Western escarpment facing the Bluegrass
Major river bottoms	E. Cumberland and Kentucky Rivers and major tributaries.

Landtype Association-A is a maturely dissected plateau having a characteristic dendritic drainage pattern. Elevation ranges from 1,000 to more than 2,500 ft. Relief ranges from 300 to nearly 1,000 ft, being greatest in the southeast and diminishing toward the southwest and the northwest.

Terrain consists of narrow, winding ridge crests; steep, often benched sideslopes; and narrow, winding valleys. Small areas of smooth land occur on mountaintops, footslopes, benches, and streambottoms.

The bedrock is interbedded sandstone, siltstone, shale, and coal. Soils on ridges and convex upper slopes formed in residuum. Soil texture is a function of elevation because strata are nearly horizontal. Soils from shale are clayey, and those from sandstone are loamy. Nearly half of LTA-A consists of soils formed in colluvium.

Narrow benches and short sandstone cliffs occur on some of the steeper slopes. Soils on ridgetops average 2 to 4 ft to rock; those on upper slopes average 1 to 3 ft, and those on colluvial slopes are 5 to more than 15 ft deep. These soils are mostly pale, loamy and clayey, friable, with varying amounts of rock fragments. Soils having dark surface layers occur in places at higher elevations and in cool, moist coves.

The narrow, winding valleys represent the majority of smooth land in LTA-A, and most of the sparse population live here. These alluvial soils are mostly deeper than 5 ft, pale, loamy, and friable. Rock fragments are common on the surface and throughout the profile of these soils.

Large tracts are owned by timber and coal companies. The Red Bird Ranger District of the Daniel Boone National Forest is located in LTA-A. Contour mining has disturbed thousands of acres and has resulted in the acidification and siltation of streams. By altering the landform, surface mining has changed drainage patterns and has affected the rate of physical and chemical processes of soil formation. Soils developing in mine spoil contain 35 to 80 percent rock and coal fragments. These young soils are well-drained, with moderately slow permeability; run-off is rapid. Reaction ranges from neutral to extremely acid.

Nearly 90 percent of LTA-A is forested with a mixture of hardwoods and conifers. Species composition and stand density vary greatly with aspect, slope position, and degree of shading from adjacent land masses. Thirteen landtypes (table 4) are recognized: 1–13.

Landtype Association-B: Low Hills Belt.—This LTA bears the name assigned to the area by Braun (1950) and coincides with the West Central Plateau Area of Bailey and Winsor (1964). It corresponds to most of soil association G-2 (Latham-Shelocta) in Kentucky. Also included are smooth, broad areas interspersed with the more rugged terrain of LTA-C along the

Table 4.—*Summary of landtypes and their frequency of occurrence by subregions and landtype associations*

Landtype number and name	Subregions[1]				
	1		2		3
	Landtype associations[1]				
	A	B	C	D	E
1. Narrow sandstone ridges and convex upper slopes	**[2]	*	**	**	
2. Narrow shale ridges, points, and convex upper slopes	**	**	*	*	
3. Shallow soils and sandstone outcrops	**	*	**	**	
4. Broad sandstone ridges—north aspect	*	***	**	*	
5. Broad sandstone ridges—south aspect	*	***	**	*	
6. Undulating shale uplands	*	**	*	*	
7. Upper mountain slopes—north aspect	***				
8. Upper mountain slopes—south aspect	***				
9. Colluvial mountain slopes, benches, and coves—north aspect	***	**			
10. Colluvial mountain slopes, benches, and coves—south aspect	***	**			
11. Surface mines	**	**	*	*	
12. Mountain footslopes, fans, terraces, and streambottoms with good drainage	**	*	*	*	
13. Mountain terraces and streambottoms with poor drainage	**	*	*	*	
14. Undulating sandstone uplands		***	**	*	
15. Upper escarpment slopes and benches—north aspect		*	***	***	
16. Upper escarpment slopes and benches—south aspect		*	***	***	
17. Lower escarpment slopes and benches—north aspect			***	***	
18. Lower escarpment slopes and benches—south aspect			***	***	
19. Shallow soils and limestone outcrops			**	***	
20. Colluvial siltstone slopes—north aspect				**	
21. Colluvial siltstone slopes—south aspect				**	
22. Limestone ridges and convex upper slopes			*	*	
23. Footslopes, terraces, and flood plains with good drainage					***
24. Terraces and flood plains with poor drainage					***

[1] See table 3 for names of subregions and landtype associations.

[2] Frequency of occurrence is common (***), frequent (**), or occasional (*). Ratings are made within each landtype association (vertically). Comparison of landtype frequency among landtype associations (horizontally) is not valid.

ennessee-Kentucky border (fig. 2). These areas were elineated as soil associations H-11 (Lily-Lonewood-amsey-Gilpin) and H-12 (Lily-Ramsey-Gilpin) in ennessee but were not recognized on the Kentucky eneral Soil Map (Soil Conservation Service 1975). I tended soil associations H-11 and H-12 along broad dges into McCreary and Wayne Counties, KY, inuding an area near Gilreath and Pine Knot designted as Clymer-Dekalb soil association in the cCreary-Whitley area soil survey (Byrne and others 70). These smoother areas along the Tennessee-entucky border are continuations of similar extenve areas in the Mid-Cumberland Plateau Region malley 1982). It would have been more appropriate assign them to the Mid-Plateau rather than have em as discontinuous parts of LTA-B in the Northern ateau region.

Soil association G-2, lying south of the Cumberland ver, was excluded from LTA-B. Nearly all of this clusion is in the Jellico Mountains, which are part the Cumberland Mountains Region (Smalley 84b). The remainder of the excluded part of soil sociation G-2 was placed in LTA-A.

Landtype Association-B is a submaturely dissected teau with a moderately dense dendritic drainage ttern. Elevation ranges from 900 to 1,500 ft. Relief nges from 150 to nearly 500 ft. Streams become re entrenched from east to west. Terrain consists of rrow winding to moderately broad ridgetops; short, ep sideslopes; and narrow V-shaped valleys. A derately extensive acreage of smooth land occurs ridgetops, and small discontinuous patches of level d occur in the narrow valleys. This smooth land is table for hay and pasture, and tobacco, corn, and all grains are the major farm crops.

andstones and conglomerates of lower Pennsylvan age are dominant in the western part of LTA-B, eastward younger Pennsylvanian shales and siltnes are more common. Loamy soils on broad ridges upper slopes formed in residuum weathered from dstone and conglomerate. Clayey soils on narrow vex ridges and upper slopes formed in residuum thered from siltstone and shale. In the western t of LTA-B a sandstone cliff separates the ridges from the sideslopes in places. Further east, intertent sandstone cliffs are common on sideslopes. -third or more of LTA-B consists of soils formed in uvium. Soils on ridgetops average 2 to 4 ft to rock, reas those on upper slopes are somewhat shaler. Soils on colluvial slopes are 5 ft or more deep. and soils are mostly pale, loamy and clayey, and ble, with varying amounts of rock fragments. Alal soils are mostly deeper than 5 ft, pale, loamy, friable.

imber and coal companies own some large tracts. nall acreage of the Daniel Boone National Forest in LTA-B. Surface mining for coal is not as extensive as in LTA-A. There is some surface mining for fire clay and some production of oil and natural gas. Problems associated with surface mining are the same as those discussed under LTA-A, but they are not as extensive or serious. Soils developed in mine spoil contain 35 to 80 percent rock and coal fragments. These young soils are well-drained, with moderately slow permeability; run-off is rapid. Reaction ranges from neutral to extremely acid. Despite its mild relief, over 70 percent of LTA-B is forested with a mixture of hardwoods and conifers. Species composition and stand density vary greatly with aspect and slope position. Because LTA-B is not as rugged as LTA's A, C, and D, the degree of shading from adjacent land masses has only a minor influence on species composition and stand density. Fourteen landtypes (table 4) are recognized: 1–6 and 9–16. Subregion 2: Western Escarpment.

Landtype Association-C: Western Escarpment facing the Eastern Highland Rim and Pennyroyal.—This LTA bears the name assigned by Bailey and Windor (1964). However, LTA-C is restricted to the part south of Rockcastle County that borders on LTA-D (weakly dissected plateau—red soils) in the Eastern Highland Rim and Pennyroyal region (Smalley 1983). It also corresponds to the southern part of Braun's (1950) Cliff Section.

Landtype Association-C coincides with the western block of soil association G-3 (Jefferson-Shelocta-Steinsburg) in Kentucky and extends into north central Tennessee, where it corresponds to soil association H-22 (Ramsey-Lily-Grimsley-Gilpin).

Landtype Association-C represents the dissected western or Pottsville escarpment of the Cumberland Plateau. The western margin is incised by numerous coves cut by the Cumberland River and its major tributaries. Elevation ranges from 1,200 to 2,200 ft, and local relief is less than 60 ft on a few smooth broad areas and 500 to 800 ft in the incised gorges and in the vicinity of points of the Plateau jutting into the Highland Rim and Pennyroyal.

This LTA consists mostly of narrow, winding ridgetops flanked by moderately steep to steep sideslopes. Low hills protrude above the general level of the Plateau, and moderately broad ridgetops occur in places. Stream channels are incised into the Plateau surface, and the narrow U-shaped or V-shaped cross-sections are bounded by nearly continuous sandstone cliffs. Close to the Plateau edge, stream channels are narrow, steep-sided, and rock-strewn. They end abruptly at the Plateau escarpment.

Soils on narrow ridgetops and upper slopes are 2 to 4 ft deep, and those on broader, smoother ridgetops are somewhat deeper. Soils from sandstone are loamy; those from shale are clayey. Colluvial soils on sideslopes and on slopes of protruding shale hills are deeper than 4 ft. Deep, stony, colluvial soils are common below the sandstone free face. The boulder-strewn escarpment usually consists of a series of short, steep slopes broken with narrow sloping benches. On toeslopes of the escarpment, soils are formed from limestone and calcareous shale. Outcrops of limestone are common.

Timber and coal companies own some large tracts. Almost all of the Stearns, Somerset, and London Ranger Districts of the Daniel Boone National Forest are situated in LTA-C. Surface mining for coal is not as extensive as in LTA-A. There is some production of oil and natural gas, particularly in Wayne County, KY. Problems associated with surface mining are the same as those discussed in LTA-A but are not as extensive or as serious. Soils developed in mine spoil contain a high percentage of rock and coal fragments. These young soils are well-drained, with moderately slow permeability; run-off is rapid. Reaction ranges from neutral to extremely acid.

Nearly three-fourths of LTA-C is forested with a mixture of hardwoods and conifers. Species composition and stand density vary greatly with aspect, slope, and degree of shading by adjacent land masses, particularly in the narrow heads of gorges. Fifteen landtypes (table 4) are recognized: 1, 3–6, 11–19, and 22.

Landtype Association-D: Western Escarpment facing the Bluegrass.—This LTA bears the name assigned by Bailey and Winsor (1964). However, LTA-D is restricted to the part north of Rockcastle County that faces the Bluegrass Region. It also corresponds to the northern part of Braun's (1950) Cliff Section. Landtype Association-D coincides with Kentucky soil association G-5 (Shelocta-Brookside-Jefferson).

Landtype Association-D lies between the Low Hills Belt (LTA-B) on the east and the Eastern Kentucky Knobs (LTA-H) of the Eastern Highland Rim and Pennyroyal Region (Smalley 1983) on the west. The boundary between the poorly defined western escarpment of the Cumberland Plateau and the strongly dissected belt of Knobs is indistinct.

This area of ridges and valleys, underlain by mid- and upper Mississippian strata, has traditionally been considered part of the Cumberland Plateau. Pennsylvanian rocks cap the higher ridges and become more prominent eastward. The Pottsville escarpment is very ragged because of the numerous coves cut by the Kentucky River and its major tributaries. Streams are entrenched in steep-sided, narrow valleys ringed with sandstone cliffs. Valleys are commonly 0.1 mi wide or less, but they gradually widen as streams progress into the Knobs Region. Rock shelters, natural bridges, and waterfalls are common. Intermittent limestone cliffs are common on mid- to lower slopes. Elevation ranges from 600 to 1,200 ft in the northern part and 1,000 to 1,500 ft in the southern end. Relief varies mostly from 150 to 400 ft but ranges to 600 ft in places.

Soils on narrow to moderately broad ridgetops are mostly 2 to 4 ft deep, loamy, well-drained, and friable. Those on steep convex upper slopes are not as deep. Colluvial soils on steep hillsides and on steep, benchy, side slopes of gorges are deeper than 5 ft, loamy, and friable. Those below sandstone cliffs have a high content of sandstone rock fragments, and large sandstone boulders cover the surface. Those below limestone cliffs have a lower content of limestone and sandstone rock fragments in the soil mass and fewer boulders on the surface. Soils in streambottoms are deep, loamy, friable. Internal drainage ranges from well-drained to poorly drained.

Timber and coal companies own some large tracts. Nearly all of the Berea and Stanton Ranger Districts are located in LTA-D. Surface mining for coal is not as extensive as in LTA-A. There is considerable productivity of oil and natural gas, particularly in Powell, Estill, and Lee Counties. Problems associated with surface mining are the same as those discussed in LTA-A but are not as extensive or as serious; salt water pollution is a problem with oil and gas drilling. Soils developed in mine spoil contain a high percentage of rock and coal fragments. These young soils are well-drained, with moderately slow permeability; run-off is rapid. Reaction ranges from neutral to extremely acid.

Nearly three-fourths of LTA-D is forested with a mixture of hardwoods and conifers. Species composition and stand density vary greatly with aspect, slope, and degree of shading by adjacent land masses, particularly in narrow gorges. Eighteen landtypes (table 4) are recognized: 1–6 and 11–22.

Subregion 3: Major River Bottoms

Landtypes Association-E: Cumberland and Kentucky Rivers and Major Tributaries.—This LTA corresponds to soil associations A-8 (Pope-Bonnie-Allegheny) and A-9 (Morehead-Whitley-Cuba) on the Kentucky General Soil Map. Soil association A-8 occurs along the Cumberland River from the Whitley-McCreary County line east to Williamsburg and south along Clear Creek. Soil association A-9 occurs along the Cumberland River upstream from Williamsburg nearly to Pineville and along the Red River in Powell County. Landtype Association-E corresponds to the Atkins-Pope-Tate soil association in the McCreary-Whitley area soil survey (Byrne and others 1970). A soil survey in progress assigns bottoms of the Cumberland River and its major tributaries in the eastern half of Whitley County and in Knox County, KY, to either the Allegheny-Huntington-Newark or the Allegheny-Cotaco-Huntington soil association[2]. Another survey in progss assigns the Elk Valley and the lower reaches of lk Creek in Campbell County, TN to the Atkins-hitley-Ealy soil association, an extension of Ken-cky general soil association A-8[3]. In Estill County, Y, Newton and others (1974) placed the bottoms of e Kentucky River and its larger tributaries in the untington-Newark-Morehead association.

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[2] Personal communication with Paul M. Love, Chief of Survey Party, Knox and East-Whitley Counties, KY. Soil Conservation Service, Barbourville, KY. 1982.

Landtype association-E is the same as LTA-H in the umberland Mountain Region (Smalley 1984b). ownstream, bottoms of the Cumberland River and s major tributaries are designated as LTA-M in the astern Highland Rim and Pennyroyal Region malley 1983) and as LTA-L in the Western High-nd Rim and Pennyroyal Region (Smalley 1980).

Landtype Association-E consists of well-drained to mewhat poorly drained, loamy and silty soils rmed in old mixed alluvium on terraces, and well-ained to poorly drained silty soils formed in more cent mixed alluvium on flood plains.

These bottoms vary from broad extensive areas arly a mile wide to narrow discontinuous strips less an 1,000 ft wide. Flood plains are nearly level or ry gently sloping, with 5 to 30 ft of relief. Terraces d footslopes are steeper, and relief may exceed 0 ft.

Fluctuating water tables and flooding limit the use this LTA and affect its management. Most of the ttoms of the Cumberland Kentucky Rivers and ir major tributaries have been cleared for agricul-e, but woodlands, some extensive, are scattered all ng these rivers. Some poorly drained land has been -drained to make it suitable for cultivation. Corn, all grains, soybeans, and legumes and tall grasses hay and pasture are major crops.

wo landtypes (table 4) are recognized: 23 and 24. ttoms of smaller rivers, creeks and streams in the rthern Cumberland Plateau region are assigned to ndtypes 12 and 13. Footslopes, terraces, alluvial s, and streambottoms in the long narrow coves t finger deeply into Landtype Association-C were cribed as Landtype 21 in the Eastern Highland n and Pennyroyal region (Smalley 1983).

LANDTYPES

have divided each landtype association into land-tyes, which are the smallest unit of the landscape regnized in this classification system. Wertz and Aold (1975) describe landtypes as visually identifi-a areas that have similar soils and productivity ar that have resulted from similar climatic and geo-lo cal processes.

The Northern Cumberland Plateau region has 24 landtypes distributed among three subregions and five landtype associations (table 4). Many are common to two or more associations, while others are characteristic of only one landtype association. In table 4, the frequency of occurrence of each landtype is qualitatively rated as common, frequent, or occasional, based on acreage within each landtype association. For example, Landtypes 7 to 10 in LTA-A dominate the landscape; Landtypes 1 to 3 and 11 to 13 are not as extensive, and Landtypes 4 to 6 comprise only a small portion of LTA-A. Comparison of landtype frequencies among landtype associations is not valid. Figures 3 to 6 depict how these landtypes occur on the landscape.

Letters in the upper right corner of each landtype description (see "Landtype Descriptions and Forest Management Interpretations") identify the landtype association(s) in which each landtype occurs. Aspect distinguishes some landtypes and is recorded as either north or south. North aspects include all azimuths from 315° (northwest) to 135° (southeast). The remainder of the azimuth circle represents south aspects.

Each landtype is described in terms of nine elements in "Landtype Descriptions and Forest Management Interpretations." The **Geographic Setting** provides an overall description of the landtype, specifying both where it occurs on the landscape and its relation to other landtypes. Slope was classified in accordance with SCS standards (Soil Survey Staff 1951).

Slope Classes and Corresponding Percent of Slope

Slope percent	Class
0–2	Level or nearly level
2–6	Gently sloping
6–10	Sloping
10–15	Strongly sloping
15–25	Moderately steep
25–45	Steep
45+	Very steep

The most prevalent soil series are listed under **Dominant Soils**. These series link this site classification system with county soil surveys published by SCS. Users who wish more detailed information can refer to soil series descriptions issued by SCS.

The kind of **Bedrock** or **Soil Parent Material** and **Depth to Bedrock** are listed next. **Soil Texture** is described in terms of the 12 conventional classes, which are based on percentages of sand, silt, and clay (Soil Survey Staff 1951).

The conventional seven **Soil Drainage** classes are: *very poorly drained, poorly drained, somewhat poorly*

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[3] onal communication with Clarence T. Conner, Chief of Survey y, Campbell County, TN. Soil Conservation Service, Jacksboro, 1982.

drained, moderately well drained, well drained, somewhat excessively drained, and *excessively drained* (Soil Survey staff 1951). **Relative Soil Water Supply** of each landtype is rated in five classes: *very low, low, medium, high,* and *very high*. This qualitative rating is based on the available water-holding capacity of the dominant soils (a function of soil texture and thickness), but allowances are made for the influence of soil drainage, topographic position, and aspect.

Soil Fertility is described as: *very low, low, moderately low, moderate, moderately high, high,* or *very high*. Most soils are fairly acid and derived from rocks with few weatherable minerals. Consequently, the most fertile soils of the Northern Cumberland Plateau region are rated only moderate, except that those along mountain streams and the Cumberland and Kentucky Rivers, which are more fertile.

The most common woody species in the overstory are listed under **Vegetation** in approximate order of abundance. Important understory species are listed also, including some distinctive herbaceous groups. Although not listed, reproduction of overstory species is usually present in the understory. Species nomenclature follows Little (1979) and Fernald (1950).

FOREST MANAGEMENT INTERPRETATIONS

Each landtype is evaluated in terms of productivity for selected species of trees and species desirability for timber production (tables 5–28). Also, each landtype is rated for five soil-related problems that may affect forest management operations.

Productivity

Productivity of commercially valuable species is expressed as site index and as average annual growth in cubic feet per acre. Site index is the total height attained by dominant and codominant trees at some specified age.

For all naturally occurring species, site indices are the means of values from soil survey interpretations for dominant soils in each landtype. Interpretations are issued by SCS as part of each soil series description. SCS personnel obtained heights and age measurements in well-stocked, even-aged, essentially unmanaged stands that had not been damaged excessively by fire, insects, disease, or grazing. These stands were located on soils representing, as nearly as possible, the modal concept of each soil series. SCS personnel then used published site index curves (Beck 1962, Broadfoot 1960, Broadfoot and Krinard 1959, Nelson and others 1961, Schnur 1937, Tennessee Valley Authority 1948,[4] and U.S. Forest Service 1929) to convert height and age data to site indices. Base age is 50 years for all species except eastern cottonwood, for which it is 30 years. Sometimes, when site indices were available for one species, estimates for other species were made by using Doolittle's (1958) site index comparisons. When necessary, I adjusted these SCS site index values for aspect and slope position based on experience and soil-site research (Carmean 1975).

In a few cases when no values were available, site indices of important species were estimated; where they occur in tables 5–28, these estimated values are enclosed in parentheses.

Average annual growth expressed in cubic feet per acre was calculated from available yield tables (Doolittle 1956, McCarthy 1933, Nelson and others 1961, Schnur 1937, U.S. Forest Service 1929, and Winters and Osborne 1935). The yield tables represent either normal or fully stocked conditions. Annual growth rates for all naturally occurring species or forest types were averaged over 50 years.

Though our productivity data are the best available, all site curves and yield tables were developed either for geographic areas larger than but including the Northern Cumberland Plateau or for areas that do not include the Northern Cumberland Plateau.

Yields were not expressed in a common merchantability standard, so care should be exercised in comparing average annual yields of species both within and between landtypes. Footnotes to table 5, which apply to subsequent tables, specify the merchantability standards used.

Management Problems

Plant Competition rates the invasion of unwanted plants after openings are made in the canopy. Plant competition is *slight* if unwanted plants do not prevent adequate natural regeneration, interfere with early growth, or restrict normal development of planted or seeded seedlings. Competition is *moderate* if unwanted plants delay establishment and hinder the growth of regenerated seedlings or if they retard the eventual development of a fully stocked stand. Competition is *severe* if unwanted plants prevent adequate restocking without extensive site preparation or special maintenance practices. Competition ratings in tables 5–28 represent regional averages, and competition on a given landtype may vary as a result of past land use.

Seedling Mortality is the loss of artificially established tree seedlings as influenced by soils and topographic conditions, assuming that planting is done properly and plant competition is insignificant. Rating is *slight* if expected mortality is zero to 25 percent, *moderate* if expected mortality is 26 to 50 percent, and *severe* if mortality is more than 50 percent. If the rating is moderate or severe, special preparation of the seedbed and special planting techniques are often necessary to insure a fully stocked stand.

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[4] Site index curves for eastern redcedar based on data from 271 plots throughout the Tennessee River Valley.

Equipment Limitations are restrictions on the use of conventional wheeled or tracked equipment. Soil and topographic characteristics such as slope, drainage, texture, and rockiness influence equipment limitations, sometimes necessitating the use of different kinds of equipment and methods of operation or restricting the season when equipment is used. Generally, limitation is *slight* if slope is 20 percent or less and farm machinery can operate efficiently during all season. The rating is *moderate* if slope is 20 to 30 percent, limiting the use of ordinary farm machinery and requiring track-type equipment or if soil wetness prevents the use of logging vehicles for 2 to 6 months in a year. The rating is *severe* if slope exceeds 30 percent, making track-type equipment inadequate and requiring power vehicles and other special equipment, or if wetness prevents use of vehicles for 6 months or more in a year.

Erosion Hazard is the degree of potential soil erosion that can occur during and after forest management operations that expose soil along roads, skid trails, fire lanes, and landing areas. The ratings assume that the forest is well-managed and protected from fire and grazing. Soil and topographic characteristics considered in rating hazard of erosion include slope, infiltration, permeability, water-holding capacity, and resistance to detachment of soil particles by rainfall and run-off. *Slight* indicates that no special measures are needed, *moderate* indicates that some attention needs to be given to erosion control, and *severe* indicates that intensive erosion-control measures are needed.

Windthrow Hazard measures how soils affect root development and how firmly soils hold trees. The hazard is *slight* if rooting depth is more than 20 in and trees withstand most winds, *moderate* if effective rooting depth is 10 to 20 in and some trees are blown down during excessive soil wetness and strong winds, and *severe* if effective rooting depth is 10 in or less and trees will not stand alone in strong winds.

Species Desirability

Three categories are used for rating **Species Desirability** of species that commonly occur on each landtype. *Most Desirable* species are those with potential for fast growth, high value, or both. *Acceptable* species are those with moderate growth rate or value. *Least desirable* species are those with slow growth, poor quality, or both. These ratings represent the average situation for the region. The presence or absence of local markets could result in a species being assigned to another category.

USING THE SYSTEM

This guide will allow professional foresters, forest landowners, landuse specialists, forest researchers, and other resource professionals to make on-site determinations of site productivity and will provide a site-dependent framework for forest management planning and forest research.

To make on-site determinations of productivity on a particular tract of land, the user must first determine the subregion and landtype association in which the particular tract of land occurs by referring to table 3 and figure 2. Landtypes common to each landtype association and their frequencies of occurrence are shown in table 4. Landtype descriptions and landscape drawings (figs. 3–6) will enable the user to identify specific landtypes. Information about productivity, severity of management problems, and species desirability are shown on pages facing the landtype descriptions (tables 5–28).

This site classification system provides a sound biological basis for forest management planning because it recognizes inherent site differences and soil-related hazards. When the system is adopted, landtypes become the basic unit of management. Continuous Forest Inventory or other forest inventory systems can easily be incorporated into this site classification system to obtain information on acreage, stocking, composition, and growth of forests by landtypes. Once productivity data are available for landtypes on a specific tract, they should be substituted for the regional values in the appropriate tables.

Users should be aware that productivity will vary within a landtype. This variation should be handled as a sampling problem dependent on the desired precision of the productivity information. To adequately sample some landtypes, users with existing inventory systems may be required to install new plots or points. Excessive variation in productivity within a landtype may indicate the need to divide that landtype into more homogeneous units.

A logical vehicle to transfer this site classification system into a valuable forest management tool is a landtype map (fig. 7) that can be used in all phases of management from day-to-day activities to long-range planning. The number and scale of maps will depend on size of ownership and how intensively one wishes to manage. Landtypes can be mapped at scales of 1:10,000 to 1:60,000, and at these scales, areas as small as 2 acres can be recognized on the larger scale maps. Smoothness of the terrain will determine maximum size. So the U.S. Geological Survey $7^1/_2$-minute quadrangle sheets (1:24,000) make excellent base maps on which to delineate landtypes. Black and white or color aerial photos, particularly stereo pairs, can also serve as base maps. A reasonable amount of ground checking should be part of the mapping process. Owners or managers of large tracts should explore the advantages of computer-generated mapping of landtypes and other physical and biological features of the landscape (Beeman 1978).

For forest researchers, this site classification sys-

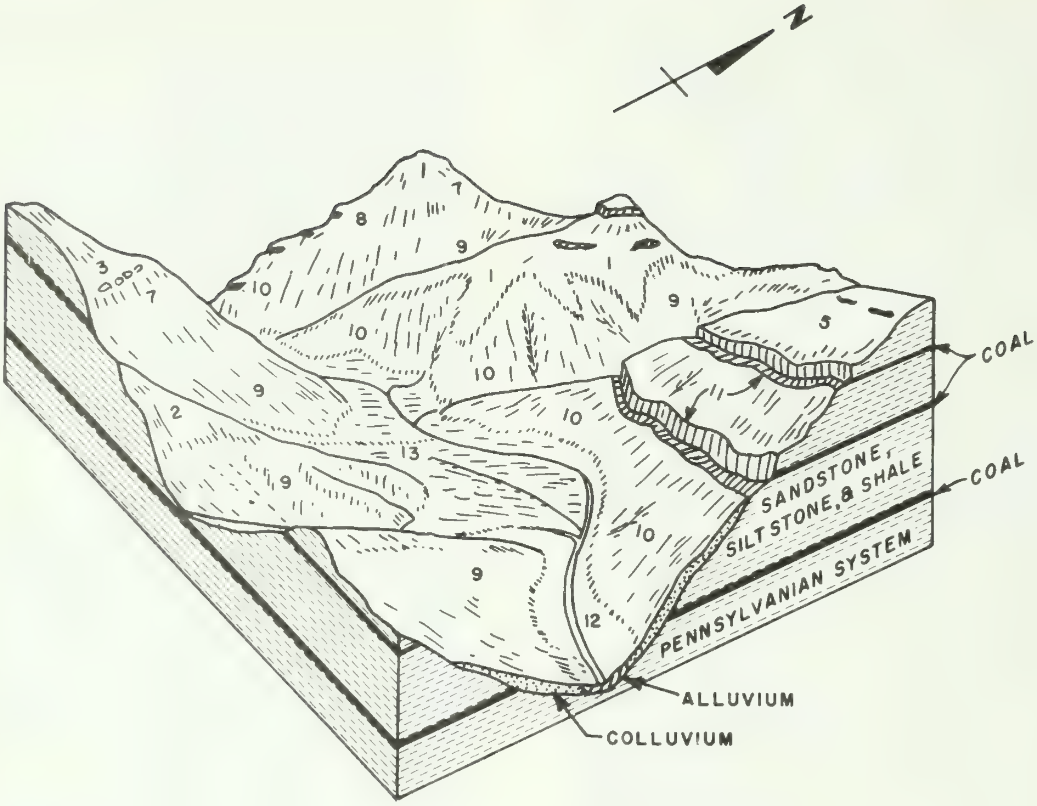

Figure 3.—*Landtypes characteristic of Landtype Association A (Rugged Eastern Area) in Subregion 1. Adapted from figures 3 and 5 in Hayes (1982).*

LEGEND

1. Narrow sandstone ridges and convex upper slopes.
2. Narrow shale ridges and convex upper slopes.
3. Shallow soils and sandstone outcrops.
5. Broad sandstone ridges—south aspect.
7. Upper mountain slopes—north aspect.
8. Upper mountain slopes—south aspect.
9. Colluvial mountain slopes—north aspect.
10. Colluvial mountain slopes—south aspect.
11. Surface mines.
12. Mountain footslopes, fans, terraces, and streambottoms with good drainage.
13. Mountain terraces and streambottoms with poor drainage.

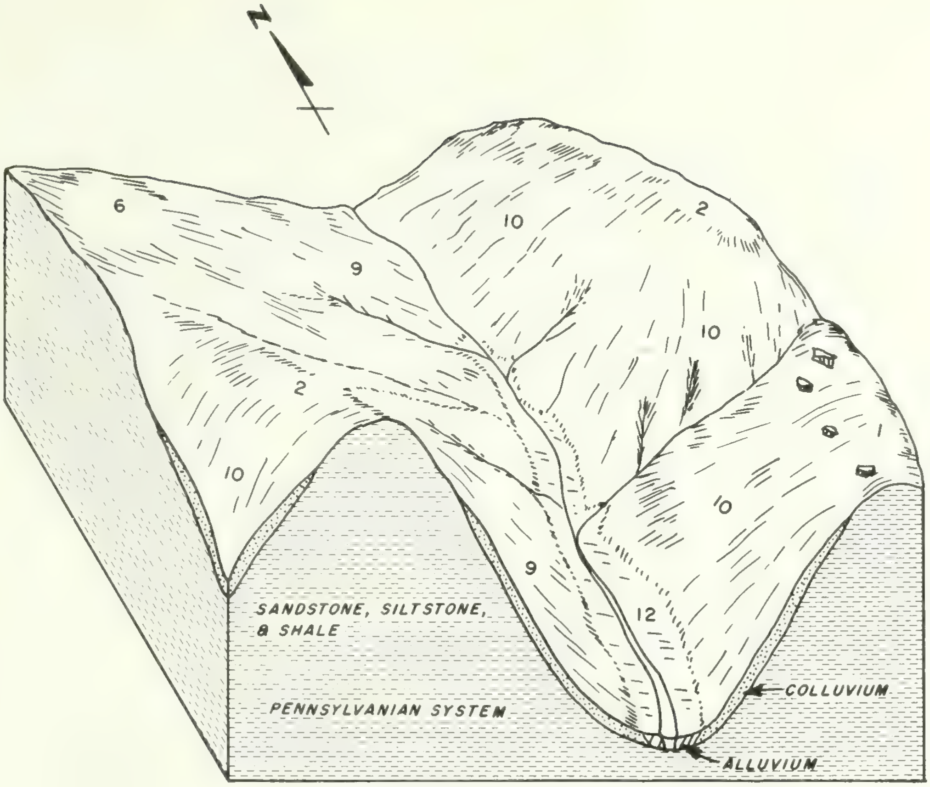

Figure 4.—*Landtypes characteristic of Landtype Association B (Low Hills Belt) in Subregion 1. Adapted from figure 8 in Newton and others (1974).*

LEGEND

1. Narrow sandstone ridges and convex upper slopes.
2. Narrow shale ridges and convex upper slopes.
6. Undulating shale uplands.
9. Colluvial mountain slopes, benches, and coves—north aspect.
10. Colluvial mountain slopes, benches, and coves—south aspect.
12. Mountain footslopes, fans, terraces, and streambottoms with good drainage.

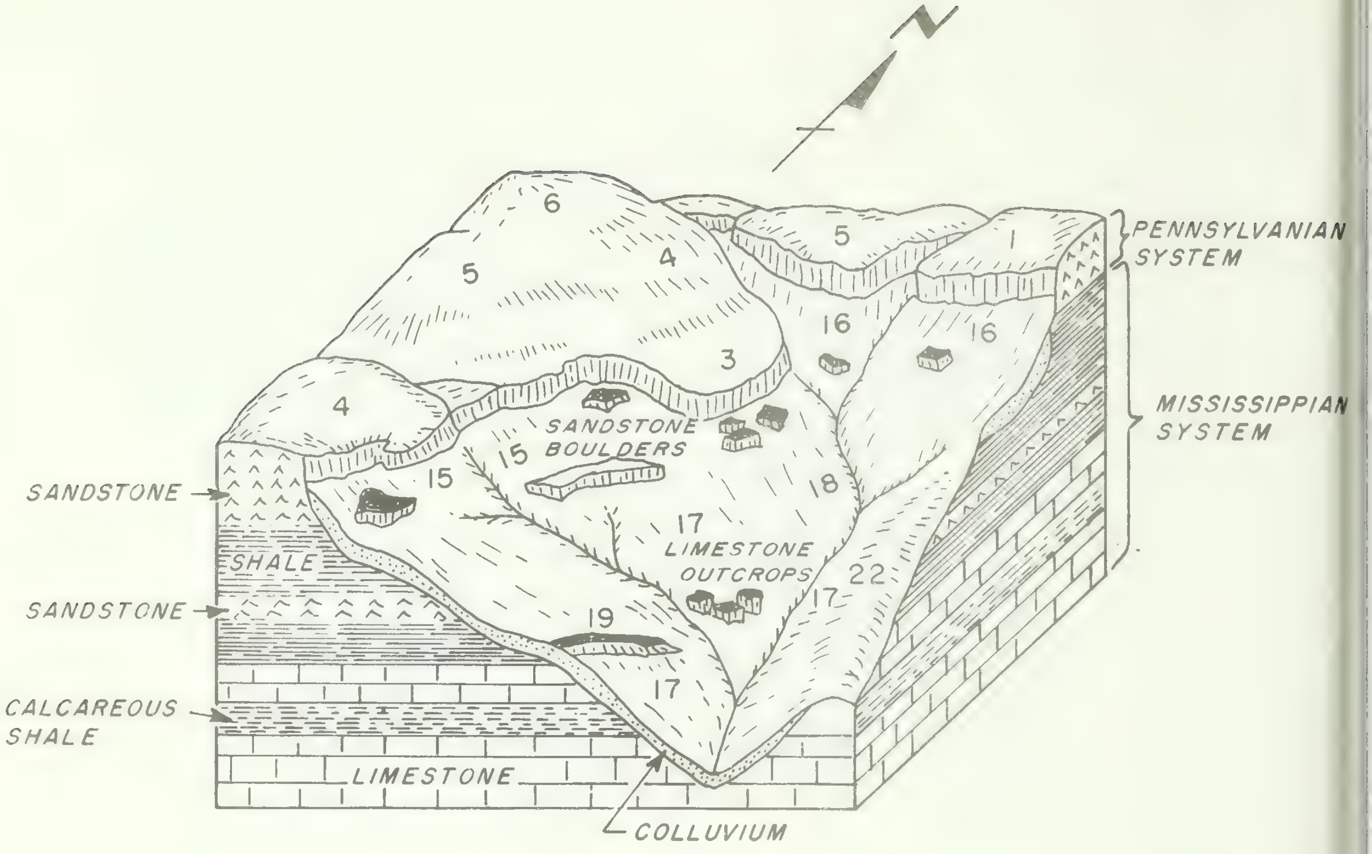

Figure 5.—*Landtypes characteristic of Landtype Association C (Western Escarpment facing the Eastern Highland Rim and Pennyroyal) in Subregion 2.*

LEGEND

1. Narrow sandstone ridges and convex upper slopes.
3. Shallow soils and sandstone outcrops.
4. Broad sandstone ridges—north aspect.
5. Broad sandstone ridges—south aspect.
6. Undulating shale uplands.
15. Upper escarpment slopes and benches—north aspect.
16. Upper escarpment slopes and benches—south aspect.
17. Lower escarpment slopes and benches—north aspect.
18. Lower escarpment slopes and benches—south aspect.
19. Shallow soils and limestone outcrops.
22. Limestone ridges and convex upper slopes.

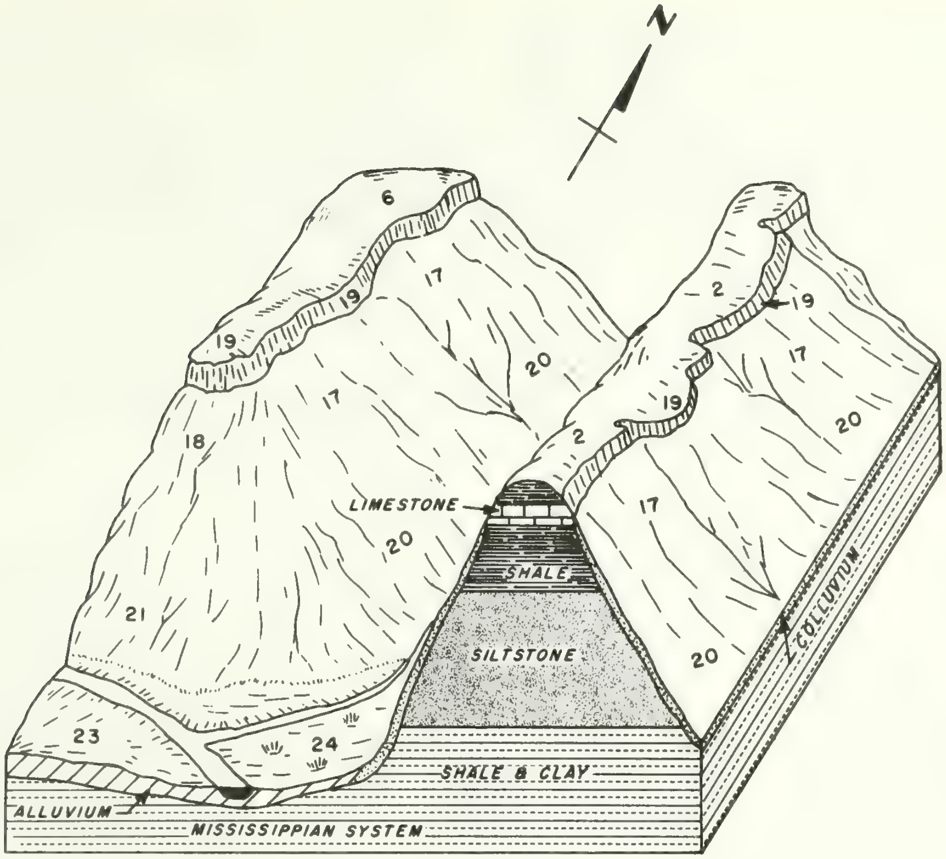

Figure 6.—*Landtypes characteristic of Landtype Association D (Western Escarpment facing the Bluegrass) in Subregion 2 and Landtype Association E (Cumberland and Kentucky Rivers and major tributaries) in Subregion 3. Adapted from figure 5 in Newton and others (1974).*

LEGEND

2. Narrow shale ridges and convex upper slopes.
6. Undulating shale uplands.
17. Lower escarpment slopes and benches—north aspect.
18. Lower escarpment slopes and benches—south aspect.
19. Shallow soils and limestone outcrops.
20. Colluvial siltstone slopes—north aspect.
21. Colluvial siltstone slopes—south aspect.
23. Footslopes, terraces, and flood plains with good drainage.
24. Terraces and flood plains with poor drainage.

tem provides a basis for stratifying study areas. The system also aids in identifying and isolating problems that need to be researched. For example, it became apparent in compiling site index and growth information that little mensuration data specific to the region are available. Finally, the system provides researchers with a vehicle for quick transfer of research results to the practitioner. Study results can be reported on the basis of their applicability to specific landtypes.

An insight into multiple-use evaluations can be found in Trimble and others (1974) for the Central Appalachians, the northern extension of the Cumberland Plateau and Mountains. McComb (1982) has summarized the knowledge on integrating forestry and wildlife management in the central hardwood region. Vogel (1981) has provided comprehensive guidelines for revegetating minesoils.

Although the northern geographical extent of the Northern Cumberland Plateau is the watershed boundary of the Kentucky River, landtypes occurring in LTA's A (Rugged Eastern Area) and B (Low Hills Belt) are applicable to the southern part of the Allegheny Plateau in northeast Kentucky—essentially general soil map associations G-3 (Jefferson-Shelocta-Steinsburg) and G-2 (Latham-Shelocta), respectively (Soil Conservation Service 1975). However, landtypes in this publication should not be applied to Kentucky soil associations G-1 (Berks-Cranston) and G-6 (Vandalia-Upshur).

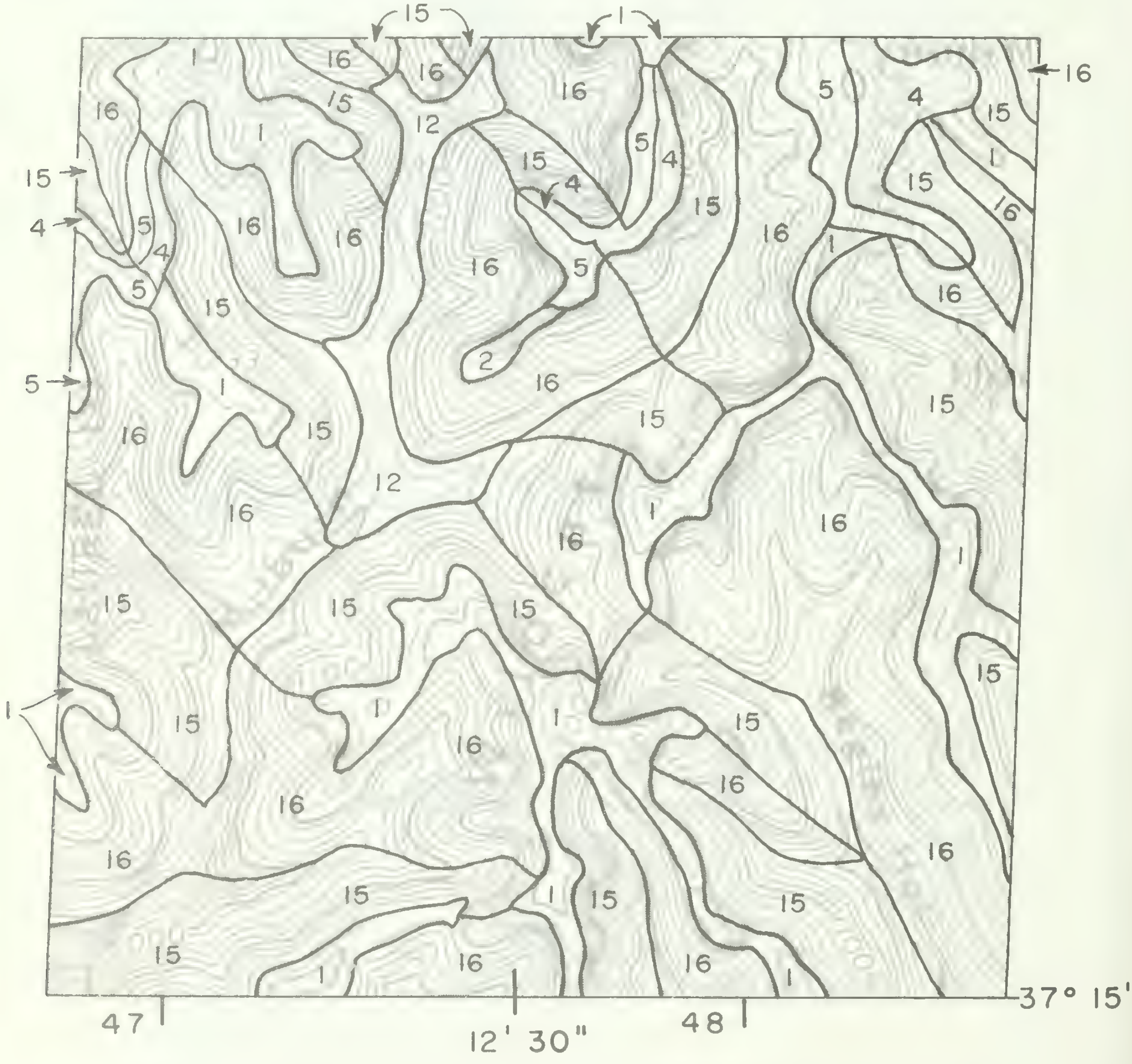

Figure 7.—*A sample landtype map showing Landtype Association-C (Western Escarpment facing the Eastern Highland Rim and Pennyroyal) in Subregion 2. Map covers a tract of about 700 acres in the southwest quarter of the Livingston Quadrangle along the Laurel-Rockcastle County Line, KY. Scale is 1:12,000. See table 4 for names of landtypes. Compare with Map 19, Soil Survey of Laurel and Rockcastle Counties, KY (Ross and others 1981).*

LANDTYPE DESCRIPTIONS AND FOREST MANAGEMENT INTERPRETATIONS

Description of Landtype 1:
Narrow Sandstone Ridges and Convex Upper Slopes

Geographic Setting—Shallow to moderately deep soils on gently sloping to steep, straight to winding, narrow ridgetops and adjoining convex upper slopes in Subregions 1 and 2. Slope ranges from 5 to 40 percent. Typically, these ridgetops are less than 300 ft wide. Soils formed mostly in loamy residuum from sandstone. Outcrops of sandstone and rock fragments on the surface are common and, in places, extensive enough to recognize Landtype 3 (shallow soils and sandstone outcrops). Landtype 1 occurs frequently in LTA's A, C, and D and occasionally in LTA-B. It usually is found in association with Landtypes 7 and 8 and, in places, with Landtypes 4, 5, and 14. Landtypes 7 and 8 usually occupy the steep upper slopes below Landtype 1, but, in places, Landtypes 9 and 10 may extend upslope to join Landtype 1. Landtype 1 also occurs in association with Landtype 11 and may be replaced by Landtype 11 following surface mining. Areas of shallow soils and sandstone outcrops may be extensive enough to recognize Landtype 3.

Dominant Soils—Ramsey, Alticrest, Wallen, Muskingum, Steinsburg, and Dekalb.

Bedrock—Horizontal to slightly tilted acid sandstone, conglomerate, and quartzite, with thin strata of siltstone and shale in places.

Depth to Bedrock—7 to 40 in.

Texture—Loam, sand loam, fine sandy loam; occasionally silt loam. Often gravelly, stony, or channery. Rock fragment content usually does not exceed 35 percent in the solum, except Wallen soils may have up to 70 percent rock fragments in the B horizon. Steinsburg and Dekalb soils may have 60 percent or more rock fragments in the C horizon.

Soil Drainage—Well-drained to somewhat excessively drained.

Relative Soil Water Supply—Low.

Soil Fertility—Low.

Vegetation—Chestnut oak, red maple, scarlet oak, hickories, black oak, white oak, Virginia pine, and southern red oak; occasional post oak, shortleaf pine, pitch pine, blackjack oak, black locust, blackgum, eastern redcedar, and eastern white pine. Sassafras, sourwood, flowering dogwood, vacciniums, sumac, persimmon, buffalo-nut, Carolina buckthorn, mountain-laurel, and azaleas are common understory species.

Table 5.—*Forest management interpretations for Landtype 1: Narrow sandstone ridges and convex upper slopes*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft^3/acre)
E. white pine	70	115
Shortleaf pine	60	102
Virginia pine	65	70
White oak	60	43

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Slight to moderate	Moderate to severe	Moderate to severe	Slight to severe	Moderate to severe

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
E. white pine	Pitch pine	E. redcedar
Shortleaf pine	Hickories	Blackjack oak
Virginia pine	Chestnut oak	Sassafras
Black oak	Scarlet oak	Black locust
White oak		Red maple
S. red oak		Blackgum
		Flowering dogwood
		Sourwood
		Persimmon

[1] Site indices for each naturally occurring species, except those enclosed in parentheses, are the means of values from soil survey interpretations issued by SCS for the dominant soils in each landtype, but sometimes adjusted for aspect and slope position (Beck 1962, Broadfoot 1960, Broadfoot and Krinard 1959, Nelson and others 1961, Schnur 1937, and U.S. Forest Service 1929). Estimated site indices are enclosed in parentheses. Base age is 50 years for all species except cottonwood, for which it is 30 years.

[2] Annual growth of natural stands calculated from published yields at 50 years: eastern white pine (Doolittle 1956), inside-bark volume of total stem, all trees; shortleaf pine (U.S. Forest Service 1929, table 108), total volume outside-bark, trees > 3.5 in d.b.h.; Virginia pine (Nelson and others 1961, table 4), outside-bark volume to a 4.0-in o.b. top, trees > 3.5 in d.b.h.; upland oaks (Schnur 1937, table 2, column 12), outside-bark volume to 4.0-in o.b. top, trees > 4.5 in d.b.h.; yellow-poplar (McCarthy 1933, table 17), inside-bark volume to 3.0-in i.b. top, trees > 4.5 in d.b.h.; sweetgum (Winters and Osborne 1935, table 13), inside-bark volume to a 4.0-in i.b. top, trees > 4.5 in d.b.h.

Description of Landtype 2: Narrow Shale Ridges, Points, and Convex Upper Slopes

Geographic Setting—Shallow to moderately deep, loamy and silty soils on sloping to very steep ridgetops, points of ridges, and adjoining convex upper slopes in Subregions 1 and 2. Typically, these shale ridges are less than 350 ft wide. Slope ranges from 6 to 80 percent and is usually more than 15 percent. On these steep, convex ridges, surface and subsurface run-off is rapid, resulting in a dry site. Aspect does not seem to be a dominant site factor. Soils formed in loamy and silty residuum from shale, siltstone, and, in places, fine-grained sandstone. Shale fragments are common on the surface. Landtype 2 occurs extensively on mountain crests at varying elevations in LTA-A and on tops of hills and ridges that project above the general level of the sandstone uplands in LTA's B and C in association with Landtypes 6, 7, and 8. Often Landtype 2 is disturbed or entirely removed during surface mining of coal if seam(s) are at relatively shallow depths (Landtype 11). Landtype 2 also occurs with Landtype 6 on hills and ridges underlain by Mississippian shales and siltstones in LTA-D in association with Landtypes 20 and 21.

Dominant Soils—Petros, Weikert, Berks, and Muskingum; possibly Gilpin, Wernock, and Latham.

Bedrock—Shale, siltstone, coal, clay, and fine-grained sandstone.

Depth to Bedrock—10 to 40 in.

Texture—Silt loam, loam, and fine sandy loam; often shaly or channery. Rock fragment content may exceed 35 percent in the solum and may be as much as 85 percent in C horizons.

Soil Drainage—Excessively drained to well-drained.

Relative Soil Water Supply—Very low to low.

Soil Fertility—Low.

Vegetation—Chestnut oak, scarlet oak, black oak, shortleaf pine, pitch pine, and Virginia pine; occasional red maple, blackgum, black locust, southern red oak, northern red oak, blackjack oak, post oak, white oak, and hickories. Flowering dogwood, vacciniums, sumac, sassafras, sourwood, buffalo-nut, azaleas, and mountain-laurel are common understory species.

Table 6.—*Forest management interpretations for Landtype 2: Narrow shale ridges, points, and convex upper slopes*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft³/acre)
Shortleaf pine	(55)	90
Virginia pine	55	41
Chestnut oak Black oak S. red oak	55	38
N. red oak	60	43

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Slight	Severe	Moderate to severe	Slight to moderate	Moderate to severe

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
Shortleaf pine	Pitch pine	Blackjack oak
Virginia pine	Hickories	Sassafras
White oak	Post oak	Black locust
Chestnut oak	S. red oak	Sumac
N. red oak	Scarlet oak	Red maple
Black oak		Blackgum
		Flowering dogwood
		Sourwood

See footnotes 1 and 2 to table 5, p. 25.

Description of Landtype 3:
Shallow Soils and Sandstone Outcrops

Geographic Setting—Small to moderately large areas of exposed sandstone, conglomerate, and quartzite and shallow to moderately deep, loamy soils formed in residuum from these same rocks in Subregions 1 and 2. Slope ranges from 8 to 70 percent. The area of exposed rock varies from a few square feet to several acres, mostly in narrow strips. Slope of the rock is nearly level. Landtype 3 is frequent in LTA's A, C, and D; occasional in LTA-B. It represents the thin to moderately thick sandstone free faces that occur intermittently on steep mountain slopes and benches (Landtypes 9 and 10). Landtype 3 occurs frequently in association with upper mountain slopes (Landtypes 7 and 8) and narrow sandstone ridges (Landtype 1) in LTA's A, B, C, and D. It occurs above the free face of the escarpment in LTA's C and D in association with sandstone ridges (Landtypes 1, 4, and 5). Landtype 3 also occurs extensively along deeply incised streams and creeks (Landtypes 12 and 13) in LTA-B and occasionally in LTA's C and D.

Dominant Soils—Ramsey and sandstone outcrops; possible Alticrest, Wallen, Steinsburg, and Dekalb.

Bedrock—Sandstone, conglomerate, and quartzite.

Depth to Bedrock—Usually less than 20 in but occasionally ranges up to 40 in in places.

Texture—Loam, sandy loam, and fine sandy loam; often stony. Rock fragment content in the solum is usually less than 35 percent, but it is more in places. Amount and size of fragments usually increase with depth.

Soil Drainage—Well-drained to somewhat excessively drained.

Relative Soil Water Supply—Very low. Seepage above exposed rock is common in wet weather, but the soil dries quickly.

Soil Fertility—Very low.

Vegetation—Chestnut oak, white oak, post oak, blackjack oak, scarlet oak, southern red oak, and blackgum; occasional Virginia pine, shortleaf pine, pitch pine, hickories, red maple, and eastern redcedar. Sourwood, flowering dogwood, winged elm, buffalo-nut, mountain-laurel, vacciniums, lichens, mosses, grasses, and Carolina buckthorn are common understory species.

Table 7.—*Forest management interpretations for Landtype 3: Shallow soils and sandstone outcrops*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft^3/acre)
Shortleaf pine	50	79
Virginia pine	55	41
E. redcedar	30	....
White oak	55	38

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Slight	Moderate to severe	Slight to severe	Slight to severe	Severe

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
Shortleaf pine	Pitch pine	Blackjack oak
Virginia pine	E. redcedar	Winged elm
	Hickories	Red maple
	White oak	Blackgum
	Post oak	Flowering dogwood
	Chestnut oak	Sourwood
	S. red oak	
	Scarlet oak	

See footnotes 1 and 2 to table 5, p. 25.

Description of Landtype 4:
Broad Sandstone Ridges—
North Aspect

Geographic Setting—Moderately deep, loamy soils on gently sloping to moderately steep north-facing portions of broad ridgetops and adjoining convex upper slopes in Subregions 1 and 2. This landtype extends from the ridge crest down to where the slope becomes linear or nearly so. At this point, gradient usually increases noticeably. Slope ranges from 6 to 20 percent and is dominantly greater than 10 percent. Soils formed in loamy residuum from sandstone or from interbedded sandstone, siltstone, and shale. Rock fragments occur on the surface in places. Landtype 4 is common in LTA-B, frequent in LTA-C, and occasional in LTA's A and D. It is associated with other sandstone ridges and uplands (Landtypes 1, 5, and 14). Hills, ridges, and associated slopes that occur above the general level of the sandstone uplands are dominated by shale and siltstone (Landtypes 2, 6, and 9). Most sandstone ridges end abruptly at the sandstone free face (Landtype 15) or merge with Landtype 3. Landtype 4 may merge with Landtypes 12 or 13 in the heads of hollows.

Dominant Soils—Lily, Alticrest, Wallen, Muskingum, Steinsburg, and Dekalb. Wallen soils are more common on south and west aspects.

Bedrock—Sandstone and conglomerate, with thin strata of shale and siltstone in places.

Depth to Bedrock—20 to 40 in.

Texture—Loam, fine sandy loam, and sandy loam; occasionally silt loam, and sometimes gravelly, stony, or flaggy. Volume of sandstone and, in places, shale fragments, in the solum is usually less than 35 percent, but deeper horizons may contain more.

Soil Drainage—Well-drained to somewhat excessively drained.

Relative Soil Water Supply—Medium.

Soil Fertility—Moderately low.

Vegetation—White oak, scarlet oak, red maple, southern red oak, chestnut oak, hickories, black oak, blackgum, shortleaf pine, and Virginia pine; occasional yellow-poplar, northern red oak, black cherry, black locust, post oak, white ash, eastern white pine, and eastern redcedar. Flowering dogwood, sassafras, serviceberry, sourwood, persimmon, buffalo-nut, lespedezas, sumac, viburnums, vacciniums, azaleas, and smilax are common understory species.

Table 8.—*Forest management interpretations for Landtype 4: Broad sandstone ridges—north aspect*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft^3/acre)
E. white pine	75	126
Shortleaf pine	65	113
Virginia pine	65	70
N. red oak	70	52
Yellow-poplar	95	98

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Moderate	Slight to moderate	Slight to moderate	Slight to moderate	Slight to moderate

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
E. white pine	Hickories	E. redcedar
Shortleaf pine	Post oak	Sassafras
Virginia pine	Chestnut oak	Serviceberry
White oak	N. red oak	Black locust
Yellow-poplar	Black oak	Red maple
Black cherry	S. red oak	Blackgum
	Scarlet oak	Flowering dogwood
	White ash	Sourwood
		Persimmon

See footnotes 1 and 2 to table 5, p. 25.

Description of Landtype 5:
Broad Sandstone Ridges—South Aspect

Geographic Setting—Moderately deep, loamy soils on gently sloping to moderately steep south-facing portions of broad ridgetops and adjoining convex upper slopes in Subregions 1 and 2. This landtype extends from the ridge crest down to where the slope becomes linear or nearly so. At this point, gradient usually increases noticeably. Slope ranges from 6 to 20 percent and is dominantly greater than 10 percent. Soils formed in loamy residuum from sandstone or from interbedded sandstone, siltstone, and shale. Rock fragments occur on the surface in places. Landtype 5 is common in LTA-B, frequent in LTA-C, and occasional in LTA's A and D. It is associated with other sandstone ridges and uplands (Landtypes 1, 4, and 14). Hills, ridges, and associated slopes that occur above the general level of the sandstone uplands are dominated by shale and siltstone (Landtypes 2, 6, and 10). Most sandstone ridges end abruptly at the sandstone free face (Landtype 16) or merge with Landtype 3. Landtype 5 may merge with Landtypes 12 or 13 in the heads of hollows.

Dominant Soils—Lily, Alticrest, Wallen, Muskingum, Steinsburg, and Dekalb. Wallen soils are more common on south and west aspects.

Bedrock—Sandstone and conglomerate with thin strata of shale and siltstone in places.

Depth to Bedrock—20 to 40 in.

Texture—Loam, fine sandy loam, and sandy loam; occasionally silt loam, and sometimes gravelly, stony, or flaggy. Volume of sandstone and, in places, shale fragments, in the solum is usually less than 35 percent, but deeper horizons may contain more.

Soil Drainage—Well-drained to somewhat excessively drained.

Relative Soil Water Supply—Medium to low.

Soil Fertility—Moderately low.

Vegetation—Chestnut oak, white oak, scarlet oak, red maple, southern red oak, hickories, black oak, post oak, blackgum, Virginia pine, and shortleaf pine; occasional black locust, yellow-poplar, eastern redcedar, and eastern white pine. Dogwoods, sassafras, sourwood, persimmon, vacciniums, sumac, viburnums, buffalo-nut, serviceberry, mountain-laurel, and smilax are common understory species.

Table 9.—*Forest management interpretations for Landtype 5: Broad sandstone ridges—south aspect*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft³/acre)
E. white pine	70	115
Shortleaf pine	60	102
Virginia pine	60	53

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Moderate	Slight to moderate	Slight to moderate	Slight	Slight to moderate

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
E. white pine	Hickories	E. redcedar
Shortleaf pine	White oak	Post oak
Virginia pine	Chestnut oak	Sassafras
	Black oak	Serviceberry
	S. red oak	Black locust
	Scarlet oak	Red maple
		Blackgum
		Dogwoods
		Sourwood
		Persimmon

See footnotes 1 and 2 to table 5, p. 25.

Description of Landtype 6:
Undulating Shale Uplands

Geographic Setting—Moderately deep, silty and clayey soils on gently sloping to moderately steep, rounded ridges and adjoining convex upper slopes in Subregions 1 and 2. Typically these undulating uplands are wider than 350 ft and maybe 1,000 ft or more wide. Slope ranges from 5 to 15 percent, but the area with slope greater than 10 percent is small and aspect is not a dominant site factor. Soils formed in silty and clayey residuum from shale, siltstone and, in places, fine-grained sandstone. Landtype 6 occurs frequently in LTA-B and only occasionally in LTA's A, C, and D. It represents the broader crests of mountains in LTA-A, the tops of higher hills and ridges that occur above the general level of the sandstone uplands in LTA's B and C, and the crests of hills and ridges in LTA-D.

Landtype 6 occurs mostly in association with Landtypes 2, 4, 5, 14, 20, and 21. In the Rugged Eastern Area (LTA-A), it occurs above Landtypes 7 and 8 and occasionally above Landtypes 9 and 10 in gaps. Landtype 6 is often disturbed by surface mining.

Dominant Soils—Latham, Sequoia, Wernock, and Gilpin.

Bedrock—Shale, siltstone, coal, clay, and fine-grained sandstone.

Depth to Bedrock—20 to 40 in.

Texture—Silt loam, loamy, and silty clay loam; occasionally shaly or channery. Rock fragment content usually is less than 35 percent in the solum but may exceed 35 percent in the C horizon.

Soil Drainage—Well-drained to moderately well-drained.

Relative Soil Water Supply—Low to medium.

Soil Fertility—Moderately low.

Vegetation—Chestnut oak, red maple, scarlet oak, black oak, hickories, shortleaf pine, Virginia pine, and white oak; occasional northern red oak, sugar maple, yellow-poplar, black locust, blackgum, elms, eastern white pine, and Fraser magnolia. Vacciniums, flowering dogwood, sumac, sassafras, sourwood, buffalo-nut, and smilax are common understory species.

Table 10.—*Forest management interpretations for Landtype 6: Broad shale ridges and convex upper slopes*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft^3/acre)
Shortleaf pine	65	113
Virginia pine	70	92
N. red oak	70	52
Yellow-poplar	75	63

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Slight to moderate	Slight	Slight to moderate	Slight	Slight

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
E. white pine	Hickories	Fraser magnolia
Shortleaf pine	Chestnut oak	Sassafras
Virginia pine	Black oak	Black locust
White oak	Scarlet oak	Sumac
N. red oak	Elms	Red maple
Yellow-poplar	Sugar maple	Blackgum
		Flowering dogwood
		Sourwood

See footnotes 1 and 2 to table 5, p. 25.

Description of Landtype 7:
Upper Mountain Slopes—North Aspect

Geographic Setting—Moderately deep, loamy and silty soils on the moderately steep to very steep upper one-fourth to one-third of north slopes in Subregion 1. These convex to linear slopes range from 16 to 75 percent in gradient. Soils formed in loamy residuum from acid siltstone, shale, and sandstone. Landtype 7 is limited to LTA-A, where it occurs below Landtypes 2, 6, and occasionally 1 and 4 and above Landtype 9. Upper reaches of Landtypes 12 and 13 may extend into Landtype 7. Areas of shallow soils and sandstone ledges may be extensive enough to recognize Landtype 3. Surface mines (Landtype 11) occur extensively in association with Landtype 7.

Dominant Soils—Muskingum, Gilpin, and Berks; possibly Dekalb and Steinsburg. Zenith and Cutshin occur on cool slopes and in coves, particularly in LTA-A. Often mapped as soil complexes.

Bedrock—Siltstone, shale, coal, and clay; possibly sandstone and conglomerate.

Depth to Bedrock—20 to 40 in. Zenith and Cutshin soils are 70 to 80 in to rock.

Texture—Silt loam, loam, fine sandy loam, and sandy loam; possibly sandy clay loam and clay loam. Rock fragment content is usually less than 35 percent in the solum, but is more in Berks and Dekalb soils. Deeper horizons may contain as much as 75 percent rock fragments.

Soil Drainage—Well-drained to somewhat excessively drained.

Relative Soil Water Supply—Medium to low.

Soil Fertility—Moderate to moderately low.

Vegetation—White oak, chestnut oak, red maple, yellow-poplar, northern red oak, black oak, and sugar maple; occasional black locust, white basswood, blackgum, shortleaf pine, Virginia pine, hickories, eastern white pine, yellow buckeye, eastern hemlock, cucumbertree, black walnut, white ash, and sweet birch. Flowering dogwood, sassafras, sumac, eastern redbud, rhododendron, serviceberry, hydrangea, mountain-laurel, buffalo-nut, and grape are common understory species.

Table 11.—*Forest management interpretations for Landtype 7: Upper mountain slopes—north aspect*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft^3/acre)
E. white pine	85	145
Shortleaf pine	80	148
Virginia pine	70	92
White oak	(75)	57
N. red oak	80	62
Black oak	70	52
Yellow-poplar	100	107

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Moderate to severe	Slight to moderate	Moderate to severe	Moderate to severe	Slight to moderate

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
E. white pine	Hickories	E. hemlock
Shortleaf pine	Chestnut oak	Sweet birch
Virginia pine	Black oak	Sassafras
Black walnut	Cucumbertree	Serviceberry
White oak	Sugar maple	E. redbud
N. red oak	Yellow buckeye	Black locust
Yellow-poplar	White basswood	Sumac
White ash		Red maple
		Flowering dogwood

See footnotes 1 and 2 to table 5, p. 25.

Description of Landtype 8:
Upper Mountain Slopes— South Aspect

Geographic Setting—Moderately deep, loamy and silty soils on moderately steep to very steep upper one-third to one-half of south slopes in Subregion 1. These convex to linear slopes range from 16 to 75 percent in gradient. Soils formed in loamy residuum from acid siltstone, shale, and sandstone. Landtype 8 is limited to LTA-A, where it occurs below Landtypes 2, 6, and occasionally 1 and 5, and above Landtype 10. Upper reaches of Landtypes 12 and 13 may extend into Landtype 8. Areas of shallow soils and sandstone ledges may be extensive enough to recognize Landtype 3. Surface mines (Landtype 11) occur extensively in association with Landtype 8.

Dominant Soils—Muskingum, Gilpin, and Berks; possible Dekalb and Steinsburg. Often mapped as soil complexes.

Bedrock—Siltstone, shale, coal, and clay; possible sandstone and conglomerate.

Depth to Bedrock—20 to 40 in.

Texture—Silt loam, loam, fine sandy loam, and sandy loam. Rock fragment content is usually less than 35 percent in the solum, but is more in Berks and Dekalb soils. Deeper horizons may contain as much as 75 percent rock fragments.

Soil Drainage—Well-drained to somewhat excessively drained.

Relative Soil Water Supply—Low.

Soil Fertility—Moderate to moderately low.

Vegetation—White oak, chestnut oak, scarlet oak, black oak, blackgum, red maple, and shortleaf pine; occasional yellow-poplar, northern red oak, hickories, black locust, Virginia pine, elms, and eastern white pine. Flowering dogwood, sassafras, sourwood, serviceberry, sumac, viburnums, vacciniums, mountain-laurel, buffalo-nut, and grape are common understory species.

Table 12.—*Forest management interpretations for Landtype 8: Upper mountain slopes—south aspect*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft^3/acre)
E. white pine	75	126
Shortleaf pine	60	102
Virginia pine	60	53
N. red oak	65	48
Black oak	60	43
Yellow-poplar	(75)	63

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Slight	Moderate	Moderate to severe	Moderate to severe	Slight to moderate

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
E. white pine	Hickories	Sassafras
Shortleaf pine	Chestnut oak	Serviceberry
Virginia pine	Black oak	Black locust
White oak	Scarlet oak	Sumac
N. red oak	Elms	Red maple
Yellow-poplar		Blackgum
		Flowering dogwood
		Sourwood

See footnotes 1 and 2 to table 5, p. 25.

Description of Landtype 9:
Colluvial Mountain Slopes, Benches, and Coves—North Aspect

Geographic Setting—Deep, loamy, often gravelly, cobbly, or stony soils on the sloping to steep lower two-thirds to three-fourths of north slopes in Subregion 1. The linear to concave slopes range from 15 to 60 percent. Soils formed in loamy colluvium from acid siltstone, shale, and sandstone. Lower parts of south-facing colluvial slopes (Landtype 10), particularly the coves, that are shaded extensively by adjacent land masses should be classified as Landtype 9. Landtype 9 is common in LTA-A and frequent in LTA-B. Landtype 9 occurs below Landtype 7 but may border on Landtypes 1, 2, 4, 6, or 14 in gaps. Upper reaches of Landtypes 12 and 13 usually extend into Landtype 9, and, in places, they merge with major river bottoms (Landtypes 23 and 24). Surface mines (Landtype 11) occur extensively in association with Landtype 9.

Dominant Soils—Jefferson, Grimsley, Shelocta, and Rigley. Zenith and Cutshin occur on cool slopes and in coves, particularly in LTA-A. Often mapped as soil complexes.

Bedrock—Siltstone, shale, coal, and clay; possibly sandstone and conglomerate.

Depth to Bedrock—40 to 120 in or more.

Texture—Loam, fine sandy loam, sandy loam, and silt loam; occasionally sandy clay loam and clay loam. Rock fragment content varies considerably, and boulders and cobbles are common on the surface, particularly in coves.

Soil Drainage—Well-drained.

Relative Soil Water Supply—Medium to high.

Soil Fertility—Moderate to moderately high.

Vegetation—Yellow-poplar, northern red oak, white oak, hickories, red maple, and American beech; occasional sugar maple, cucumbertree, yellow buckeye, eastern hemlock, eastern white pine, black oak, white ash, blackgum, white basswood, and black birch. Flowering dogwood, American hornbeam, vacciniums, grape, viburnums, hydrangea, spicebush, pawpaw, and strawberry-bush are common understory species.

Table 13.—*Forest management interpretations for Landtype 9: Colluvial mountain slopes, benches, and coves—north aspect*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft^3/acre)
E. white pine	85	145
Shortleaf pine	75	136
Virginia pine	75	120
White oak	75	57
N. red oak	80	62
Yellow-poplar	100	107

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Moderate to severe	Slight to moderate	Moderate to severe	Moderate to severe	Slight

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
E. white pine	Hickories	E. hemlock
White oak	American beech	Black birch
N. red oak	Cucumbertree	American hornbeam
Black oak	Sugar maple	Serviceberry
Yellow-poplar	Yellow buckeye	Sumac
White ash	White basswood	Red maple
		Blackgum
		Flowering dogwood
		Sourwood

See footnotes 1 and 2 to table 5, p. 25.

Description of Landtype 10:
Colluvial Mountain Slopes, Benches, and Coves—South Aspect

Geographic Setting—Deep, loamy, often gravelly, cobbly, or stony soils on the sloping to steep lower one-half to two-thirds of south slopes in Subregion 1. The linear to concave slopes range from 15 to 60 percent. Soils formed in loamy colluvium from acid siltstone, shale, and sandstone. Lower parts of these slopes particularly the coves, may be shaded extensively by adjacent land masses and should be classified as having a north aspect (Landtype 9). Landtype 10 is common in LTA-A and frequent in LTA-B. Landtype 10 occurs below Landtype 8, but may border on Landtypes 1, 2, 5, 6, or 14 in gaps. Upper reaches of Landtypes 12 and 13 usually extend into Landtype 10, and, in places, it merges with major river bottoms (Landtypes 23 and 24). Surface mines (Landtype 11) occur extensively in association with Landtype 10.

Dominant Soils—Jefferson, Grimsley, Shelocta, and Rigley. Often mapped as complexes.

Bedrock—Siltstone, shale, coal, and clay; possibly sandstone and conglomerate.

Depth to Bedrock—40 to 120 in or more.

Texture—Loam, fine sandy loam, sandy loam, and silt loam; occasionally sandy clay loam and clay loam. Rock fragment content varies considerably within short distances. Boulders and cobbles are common on the surface, particularly in coves.

Soil Drainage—Well-drained.

Relative Soil Water Supply—Medium.

Soil Fertility—Moderate to moderately high.

Vegetation—White oak, chestnut oak, scarlet oak, red maple, hickories, black oak, Virginia pine, and shortleaf pine; occasional northern red oak, yellow-poplar, sugar maple, black locust, eastern hemlock, American beech, blackgum, and white ash. Flowering dogwood, American hornbeam, sassafras, eastern redbud, grape, hydrangea, sumac, pawpaw, and spicebush are common understory species.

Table 14.—*Forest management interpretations for Landtype 10: Colluvial mountain slopes, benches, and coves—south aspect*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft³/acre)
Shortleaf pine	65	135
Virginia pine	70	92
White oak N. red oak	70	52
Yellow-poplar	(85)	80

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Moderate	Moderate	Moderate to severe	Moderate to severe	Slight

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
Shortleaf pine	Hickories	E. hemlock
Virginia pine	American beech	American hornbeam
White oak	Chestnut oak	Sassafras
N. red oak	Black oak	E. redbud
Yellow-poplar	Scarlet oak	Black locust
White ash	Sugar maple	Sumac
		Red maple
		Blackgum
		Flowering dogwood

See footnotes 1 and 2 to table 5, p. 25.

Description of Landtype 11:
Surface Mines

Geographic Setting—Nearly vertical high walls and young, loamy, rocky soils forming in heterogeneous spoil resulting from area, contour, and auger types of surface mining for coal in Subregions 1 and 2. No distinction is made between unreclaimed (orphan) and reclaimed surface mines.

In contour and auger mining (common in LTA-A) the spoil is smoothed to form benches with steep to very steep outer slopes and to partially cover the high wall. Benches ranges from 70 to 150 ft or more in width, and the high walls are generally 60 ft or more high. Contour mines occur at all elevations on mountain sides and tops. Nearly on the contour, they extend around the mountains in strips that range from a few hundred yards to several miles and encompass areas as large as 250 acres. Slopes are dominantly 12 to 20 percent on benches and 25 to 80 percent on outslopes. Ponds between the high wall and the spoil bank are common on orphan mines.

In area mining (common in LTA's B, C, and D) reclamation standards require restoration to about pre-mining topography. Area mining operations may cover several hundreds of acres. Slopes are usually less than 15 percent except in the vicinity of the final trench and in the heads of hollows at the margins of operations. Siltation ponds are now required on area mines.

Dominant Soils—Fairpoint and Bethesda. Formerly mapped as minespoils and surface mines. Reaction of Fairpoint soils is neutral to medium acid; that of Bethesda soils is strongly acid to extremely acid.

Parent Material—Formed in acid to neutral regolith from surface mining and occasionally in refuse from deep mining. Rock fragments consist of siltstone, shale, coal, and fine and medium-grained sandstone. Fine-earth material is partially weathered rock fragments.

Depth to Bedrock—50 in to 50 ft or more.

Texture—The A horizon of unreclaimed areas is shaly, channery, or gravelly clay loam, silty clay loam, or silt loam. Reclaimed areas have 4- to 12-in-thick A horizons from natural soil material with texture of silt loam, loam, silty clay loam, or clay loam. Thirty-five to 80 percent of the C horizons are composed of rock fragments.

Soil Drainage—Well-drained.

Relative Soil Water Supply—Low to medium.

Soil Fertility—Low. Soil reaction ranges from neutral to extremely acid, except surface layers that have been limed. Toxicities and deficiencies of plant nutrients are common in strongly and extremely acid soils. Shrink-swell potential is moderate.

Vegetation—Reclaimed areas have been seeded to grasses and/or legumes. Plantings of black locust, shortleaf pine, Virginia pine, and eastern white pine are common on all sites while yellow-poplar, green ash, American sycamore, and sweetgum have been planted on cool and/or moist to wet sites. Unreclaimed mine soils have slowly revegetated naturally, and species occurrence depends on age of the spoil. Common native woody species are eastern redcedar, yellow-poplar, black locust, red maple, Virginia pine, shortleaf pine, American sycamore, winged elm, hickories, white oak, scarlet oak, blackgum, post oak, blackjack oak, chestnut oak, black oak, sweetgum, black willow, cottonwood, river birch, sumac, persimmon, and sassafras. Two common exotic species are white poplar and royal paulownia. Consult Vogel's (1981) guide for specific recommendations for revegetating mine soils.

Table 15.—*Forest management interpretations for Landtype 11: Surface mines*[1]

MANAGEMENT PROBLEMS				
Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Slight	Severe	Slight to severe	Severe	Slight

SPECIES DESIRABILITY		
Most desirable	Acceptable	Least desirable
E. white pine	E. redcedar	White poplar
Shortleaf pine	Hickories	Black willow
Virginia pine	Post oak	River birch
E. cottonwood	Chestnut oak	Blackjack oak
White oak	Black oak	Winged elm
Yellow-poplar	Scarlet oak	Sassafras
Sweetgum	Black locust	Sumac
American sycamore	Red maple	Blackgum
	Green ash	Persimmon
		Royal paulownia

[1] Data not available on productivity (species, site index, and average annual growth).

Description of Landtype 12:
Mountain Footslopes, Fans, Terraces, and Streambottoms with Good Drainage

Geographic Setting—Deep, silty and loamy alluvial soils with good internal drainage on level to strongly sloping footslopes, fans, terraces, and streambottoms along streams and creeks in Subregions 1 and 2. Slope ranges from 0 to 15 percent but is generally less than 6 percent. Landtype 12, in association with Landtype 13, occurs as long, narrow, winding, sometimes discontinuous strips of land bordering drainages. Short sandstone cliffs (Landtype 3) often separate the slopes and ridges from the terraces and streambottoms. Upper reaches of Landtype 12 extend into Landtypes 9 and 10 and occasionally into Landtypes 7 and 8 in LTA-A. In less rugged terrain, heads of hollows may extend into Landtypes 4, 5, and 14. Below the sandstone free face, Landtype 12 occurs in association with Landtypes 15 to 18, 20, and 21.

Dominant Soils—Whitley, Rowdy, Cotaco, Barbourville, and Combs on footslopes, fans, and terraces; Cuba, Steff, Clifty, Grigsby, Pope, Philo, Skidmore, Ealy, and Sewanee on streambottoms.

Parent Material—Alluvium washed from soils formed in residuum and colluvium from acid sandstone, siltstone, and shale, and possibly limestone and calcareous shale.

Depth to Bedrock—40 in to 20 ft or more.

Texture—Loam, silt loam, fine sandy loam, and sandy loam; occasionally gravelly. Rock fragment content ranges from 0 to 35 percent in the solum and to 60 percent in lower B and C horizons.

Soil Drainage—Well-drained to moderately well-drained.

Relative Soil Water Supply—High. Irrigated by subsurface flow. Seeps occur on footslopes in winter and spring. Streambottoms have seasonal water table at depths of 2 to 5 ft for 1 to 3 months. This landtype is subject to frequent flash floods following short, high intensity storms and occasional general flooding following long, sustained storms.

Soil Fertility—Moderately high to high.

Vegetation—White oak, yellow-poplar, red maple, blackgum, sweetgum, and black oak; occasional northern red oak, American sycamore, scarlet oak, eastern white pine, eastern hemlock, shagbark hickory, shortleaf pine, black willow, American elm, American beech, boxelder, black walnut, and river birch. Dogwoods, sassafras, sourwood, umbrella magnolia, American hornbeam, eastern hophornbeam, sumac, mountain-laurel, viburnums, azaleas, and cane are common understory species.

Table 16.—*Forest management interpretations for Landtype 12: Mountain footslopes, fans, terraces, and streambottoms with good drainage*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft^3/acre)
E. white pine	90	154
Shortleaf pine	80	148
Virginia pine	75	120
N. red oak	80	62
Yellow-poplar	100	107
Sweetgum	90	81
American sycamore	(90)	. . . .

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Severe	Slight	Slight to moderate	Slight	Slight

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
E. white pine	Shagbark hickory	E. hemlock
Shortleaf pine	Black oak	Black willow
Black walnut	Scarlet oak	River birch
White oak	American elm	American hornbeam
N. red oak		E. hophornbeam
Yellow-poplar		American beech
Sweetgum		Umbrella magnolia
American sycamore		Sassafras
		Red maple
		Boxelder
		Blackgum
		Dogwoods
		Sourwood

See footnotes 1 and 2 to table 5, p. 25.

Description of Landtype 13: Mountain Terraces and Streambottoms with Poor Drainage

Geographic Setting—Deep, silty and loamy alluvial soils with poor internal drainage on level to gently sloping terraces and streambottoms along streams and creeks in Subregions 1 and 2. Slope ranges from 0 to 4 percent. Landtype 13, in association with Landtype 12, occurs as long, narrow, discontinuous strips of land bordering mountain streams. Short sandstone cliffs (Landtype 3) often separate the slopes and ridges from the terraces and streambottoms. Upper reaches of Landtype 13 extend into Landtypes 9 and 10, and occasionally into Landtypes 7 and 8 in LTA-A. In less rugged terrain, heads of hollows may extend into Landtypes 4, 5, and 14. Below the sandstone free face, Landtype 13 occurs in association with Landtypes 15 to 18, 20, and 21.

Dominant Soils—Morehead on terraces; Stendal, Bonnie, Atkins, Stokly, and Bonair on streambottoms.

Parent Material—Alluvium washed from soils formed in residuum and colluvium from acid sandstone, siltstone, and shale.

Depth to Bedrock—40 in to 10 ft or more.

Texture—Silt loam and silty clay loam; occasionally sand loam and loam. Rock fragment content is 20 percent or less in the solum, but ranges to 40 percent in lower B and C horizons.

Soil Drainage—Somewhat poorly drained to poorly drained.

Relative Soil Water Supply—High to very high. Water stands on the surface or the water table is a foot or less below the surface for appreciable periods. This landtype is subject to frequent flash floods following short, high-intensity storms and occasional general flooding following long, sustained storms.

Soil Fertility—Moderately high to high.

Vegetation—Red maple, sweetgum, blackgum, yellow-poplar, white oak, American sycamore; occasional E. cottonwood, pin oak, American elm, American beech, black willow, boxelder, and silver maple. Viburnums, azaleas, mountain-laurel, rhododendron, American holly, cane, sphagnum moss, alder, dogwoods, grasses, and sedges are common in the understory.

Table 17.—*Forest management interpretations for Landtype 13: Mountain terraces and streambottoms with poor drainage*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft^3/acre)
E. cottonwood	105	....
Pin oak	95	....
Yellow-poplar	90	90
Sweetgum	90	81
American sycamore	(90)	....

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Moderate to severe	Moderate to severe	Severe	Slight	Slight

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
E. cottonwood	American elm	Black willow
White oak	Red maple	American beech
Pin oak	Boxelder	American holly
Yellow-poplar		Silver maple
Sweetgum		Blackgum
American sycamore		Dogwoods

See footnotes 1 and 2 to table 5, p. 25.

Description of Landtype 14:
Undulating Sandstone Uplands

Geographic Setting—Moderately deep to deep, loamy and silty soils on nearly level to rolling broad uplands that typically occupy the smoother, but not necessarily the highest parts, of the landscape in Subregions 1 and 2. Slope does not exceed 15 percent, but the area with slope greater than 10 percent is small and aspect is not a dominant site factor. These broad ridges range up to 0.5 mi in width. Soils formed in loamy residuum from acid sandstone, siltstone, and shale. Landtype 14 is most common in LTA-B but occurs in LTA's C and D. It occurs in association with other sandstone ridges (Landtypes 1, 4, and 5). Hills and ridges that occur above these uplands are dominated by shale and siltstone (Landtypes 2, 6, and 9). The heads of hollows (Landtypes 12 and 13) may extend into Landtype 12.

Dominant Soils—Lily, Clarkrange, Lonewood, Crossville, Tilsit, and Clymer.

Bedrock—Acid sandstone, conglomerate, siltstone, and shale.

Depth of Bedrock—20 to 90 in. Clarkrange and Tilsit soils have fragipans at depths of 18 to 28 in.

Texture—Loam, fine sandy loam, sandy loam, and possibly silt loam. Rock fragment content is 10 percent or less in the solum, but deeper horizons may contain as much as 70 percent.

Soil Drainage—Well-drained, except for Clarkrange and Tilsit, which are moderately well-drained.

Relative Soil Water Supply—Medium.

Soil Fertility—Moderately low.

Vegetation—White oak, scarlet oak, chestnut oak, red maple, southern red oak, hickories, black oak, blackgum, shortleaf pine, and Virginia pine; occasional yellow-poplar, post oak, northern red oak, sweetgum, black locust, eastern white pine, black cherry, and eastern redcedar. Flowering dogwood, sassafras, sourwood, serviceberry, sumac, hawthorns, viburnums, azaleas, American holly, and smilax are common understory species.

Table 18.—*Forest management interpretations for Landtype 14: Undulating sandstone mountain uplands*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft^3/acre)
E. white pine	80	136
Shortleaf pine	65	113
Virginia pine	70	92
White oak	70	52
N. red oak	70	
Yellow-poplar	90	90

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Slight to moderate	Slight	Slight	Slight	Slight

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
E. white pine	Hickories	E. redcedar
Shortleaf pine	Post oak	Sassafras
Virginia pine	Chestnut oak	Serviceberry
White oak	Black oak	Hawthorns
N. red oak	S. red oak	Black locust
Yellow-poplar	Scarlet oak	Sumac
Black cherry	Sweetgum	American holly
		Red maple
		Blackgum
		Flowering dogwood
		Sourwood

See footnotes 1 and 2 to table 5, p. 25.

Description of Landtype 15:
Upper Escarpment Slopes and Benches—North Aspect

Geographic Setting—Deep to very deep, loamy soils formed in colluvium from sandstone, siltstone, and shale and underlain by similar rocks in subregions 1 and 2. Landtype 15 occupies the gently sloping to very steep upper one-third to one-half of northerly slopes that extend from the Plateau sandstone free face to the adjacent Eastern Highland Rim and Pennyroyal and Bluegrass regions or it borders coves and gorges that may extend several miles into the interior of the Plateau. Slope ranges from 5 to 70 percent. Much of the surface is covered with sandstone boulders and fragments. In LTA-B, the sandstone free face may occur one-fourth to one-third of the distance from the ridgetop to the streambottom. Here a short colluvial slope, similar to Landtype 15, may occur between the free face and the ridge (Landtypes 1, 2, 4, or 6). Landtype 15 occurs above Landtypes 12 and 13 or 23 and 24 in gorges of the Plateau interior where streams have not cut through the sandstone caprock. Where streams have cut through the sandstone caprock into the underlying Mississippian rocks, Landtype 15 occurs above Landtype 17. In the upper reaches of narrow gorges, the lower one-fourth to one-half of south-facing upper slopes (Landtype 16) should be included with Landtype 15 because shading mollifies the normal warm microclimate. As gorges widen, the effect of shading diminishes.

Dominant Soils—Grimsley, Jefferson, Shelocta, Rigley, and Zenith; possibly pockets of Ramsey, Alticrest, and Steinsburg. Formerly mapped as sandstone rockland or bouldery colluvial land.

Bedrock—Sandstone, siltstone, and shale.

Depth to Bedrock—40 to 60 in or more, except for Ramsey, Alticrest, and Steinsburg, which are less than 40 in deep.

Texture—Gravelly or cobbly loam, silt loam, sandy clay loam, or clay loam.

Soil Drainage—Well-drained.

Relative Soil Water Supply—Very high to high. Irrigated by subsurface flow and seepage.

Soil Fertility—Moderate to moderately low.

Vegetation—White oak, northern red oak, yellow-poplar, chestnut oak, sugar maple, hickories, American beech, black oak, white ash, white basswood, yellow buckeye, and black locust; occasional blackgum, elms, red maple, southern red oak, eastern hemlock, eastern white pine, chinkapin oak, sweet birch, black cherry, black walnut, and cucumbertree. Dogwood, eastern redbud, bigleaf magnolia, spicebush, bladdernut, hydrangea, viburnums, azaleas, rhododendrons, sourwood, grape, and pawpaw are common understory species. This landtype also supports a rich herbaceous flora.

Table 19.—*Forest management interpretations for Landtype 15: Upper escarpment slopes and benches—north aspect*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft^3/acre)
Black walnut	(90)	......
White oak	75	57-62
N. red oak	80	
S. red oak	75	
Yellow-poplar	100	107
Black cherry	(90)	......
White ash	(90)	......

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Moderate	Slight	Moderate to severe	Slight to moderate	Slight

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
Black walnut	E. white pine	E. hemlock
White oak	Sweet birch	American beech
N. red oak	Chinkapin oak	E. redbud
Yellow-poplar	Black oak	Black locust
Black cherry	S. red oak	Red maple
White ash	Elms	Blackgum
	Cucumbertree	Dogwood
	Sugar maple	Sourwood
	Yellow buckeye	
	White basswood	

See footnotes 1 and 2 to table 5, p. 25.

Description of Landtype 16:
Upper Escarpment Slopes and Benches—South Aspect

Geographic Setting—Deep to very deep, loamy soils formed in colluvium from sandstone, siltstone, and shale and underlain by similar rocks in Subregions 1 and 2. Landtype 16 occupies the gently sloping to very steep upper one-third to one-half of southerly slopes that extend from the Plateau sandstone free face to the adjacent Eastern Highland Rim and Pennyroyal and Bluegrass regions or it borders coves and gorges that may extend several miles into the interior of the Plateau. Slope ranges from 5 to 70 percent. Much of the surface is covered with sandstone boulders and fragments. In LTA-B, the sandstone free face may occur one-fourth to one-third of the distance from the ridgetop to the streambottom. Here a short colluvial slope, similar to Landtype 16, may occur between the free face and the ridge (Landtypes 1, 2, 5, or 6). Landtype 16 occurs above Landtypes 12 and 13 or 23 and 24 in gorges of the Plateau interior where streams have not cut through the sandstone caprock. Where streams have cut through the sandstone caprock into the underlying Mississippian rocks, Landtype 16 occurs above Landtype 18. In the upper reaches of narrow gorges, the lower one-fourth to one-half of Landtype 16 should be included with north-facing upper slopes (Landtype 15) because shading mollifies the normal warm microclimate. As gorges widen, the effect of shading diminishes.

Dominant Soils—Grimsley, Jefferson, Shelocta, and Rigley; possibly pockets of Ramsey, Alticrest, and Steinsburg. Formerly mapped as sandstone rockland or bouldery colluvial land.

Bedrock—Sandstone, siltstone, and shale.

Depth to Bedrock—40 to 60 in or more, except for Ramsey, Alticrest, and Steinsburg, which are less than 40 in deep.

Texture—Gravelly or cobbly loam, silt loam, sandy clay loam, or clay loam.

Soil Drainage—Well-drained.

Relative Soil Water Supply—Medium to low. Irrigated by subsurface flow and seepage. This landtype is not as moist as Landtype 15.

Soil Fertility—Moderate low to low.

Vegetation—White oak, chestnut oak, northern red oak, hickories, black oak, red maple, yellow-poplar, and black locust; occasional blackgum, elms, eastern white pine, white ash, black cherry, southern red oak, shortleaf pine, and Virginia pine. Dogwood, viburnums, eastern redbud, sourwood, azaleas, and grape are common understory species.

Table 20.—*Forest management interpretations for Landtype 16: Upper escarpment slopes and benches—south aspect*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft^3/acre)
Shortleaf pine	65	113
Virginia pine	70	92
White oak	(65)	48
N. red oak	65	
S. red oak	(65)	

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Slight	Moderate	Moderate to severe	Slight to moderate	Slight

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
E. white pine	Hickories	E. redbud
Shortleaf pine	Black locust	Red maple
Virginia pine	N. red oak	Blackgum
White oak	Elms	Dogwood
Chestnut oak	Yellow-poplar	Sourwood
Black oak	Black cherry	
S. red oak	White ash	

See footnotes 1 and 2 to table 5, p. 25.

Description of Landtype 17:
Lower Escarpment Slopes and Benches—North Aspect

Geographic Setting—Moderately deep to deep loamy and clayey soils formed in colluvium from limestone, shale, siltstone, and sandstone and in limestone residuum, and underlain by limestone, siltstone, and shale in Subregion 2. Landtype 17 occupies the gently sloping to very steep lower one-half to two-thirds of north slopes that extend from the Plateau sandstone free face to the adjacent Eastern Highland Rim and Pennyroyal and Bluegrass regions or it borders coves and gorges that may extend several miles into the interior of the Plateau. It also occurs on northern slopes of narrow spur ridges below Landtype 22 in LTA-C and colluvial slopes below intermittent limestone cliffs in LTA-D. Slope ranges from 2 to 75 percent. Outcrops of limestone may cover up to 40 percent of the surface, but sandstone boulders also may be present. Shallow soils and limestone outcrops may be extensive enough to recognize Landtype 19; often mapped as soil complexes. Landtype 17 is absent in gorges of the Plateau where streams have not cut through the sandstone caprock. Where streams have cut through the sandstone caprock into the underlying Mississippian rocks, this landtype usually occurs downslope from Landtype 15 and above Landtypes 12 and 13 or 23 and 24. In the lower reaches of narrow gorges, some or all of south-facing lower slopes (Landtype 18) should be included with Landtype 17 because shading mollifies the normal warm microclimate. As gorges widen, the effect of shading diminishes.

Dominant Soils—Bouldin, Brookside, Shelocta, and Talbott. Formerly mapped as limestone rockland or bouldery colluvial land.

Bedrock—Limestone; occasionally siltstone and shale.

Depth to Bedrock—Mostly 60 in or more but may be 20 to 40 in where Talbott soils occur.

Texture—Channery to stony loam, sandy loam, silt loam, and silty clay loam.

Soil Drainage—Well-drained and moderately well-drained.

Relative Soil Water Supply—Medium to low. Usually soil water percolates deep into the limestone, but seeps and springs are associated with Brookside soils.

Soil Fertility—Moderate to moderately low.

Vegetation—White oak, chestnut oak, northern red oak, black oak, hickories, scarlet oak, and yellow-poplar; occasional blackgum, red maple, sugar maple, eastern white pine, post oak, eastern redcedar, chinkapin oak, hackberry, black walnut, and elms. Dogwood, eastern redbud, winged elm, viburnums, sumac, ironwood, and hawthorns are common in the understory.

Table 21.—*Forest management interpretations for Landtype 17: Lower escarpment slopes and benches—north aspect*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft^3/acre)
E. redcedar	45	....
White oak	70	52–62
N. red oak	80	
Yellow-poplar	90	90

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Moderate	Slight to moderate	Moderate to severe	Moderate to severe	Slight

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
Black walnut	E. redcedar	Ironwood
White oak	E. white pine	Winged elm
N. red oak	Hickories	Hackberry
Black oak	Post oak	E. redbud
Yellow-poplar	Chestnut oak	Blackgum
	Chinkapin oak	Dogwood
	Scarlet oak	
	Elms	
	Sugar maple	

See footnotes 1 and 2 to table 5, p. 25.

Description of Landtype 18:
Lower Escarpment Slopes and Benches—South Aspect

Geographic Setting—Moderately deep to very deep, loamy and clayey soils formed in colluvium from limestone, shale, siltstone, and sandstone and in limestone residuum, and underlain by limestone, siltstone, and shale in Subregion 2. Landtype 18 occupies the gently sloping to very steep lower one-half to two-thirds of south slopes that extend from the Plateau sandstone free face to the adjacent Eastern Highland Rim and Pennyroyal and Bluegrass regions or it borders coves and gorges that may extend several miles into the interior of the Plateau. It also occurs on southern slopes of narrow spur ridges below Landtype 22 in LTA-C and on colluvial slopes below intermittent limestone cliffs in LTA-D. Slope ranges from 2 to 75 percent. Outcrops of limestone may cover up to 40 percent of the surface, but sandstone boulders also may be present. Shallow soils and limestone outcrops may be extensive enough to recognize Landtype 19; often mapped as complexes. Landtype 18 is absent in gorges of the Plateau where streams have not cut through the sandstone caprock. Where streams have cut through the sandstone caprock into the underlying Mississippian rocks, this landtype usually occurs downslope from Landtype 16 and above Landtypes 12 and 13 or 23 and 24. In the lower reaches of narrow gorges, some or all of Landtype 18 should be included with north-facing lower slopes (Landtype 17) because shading mollifies the normal warm microclimate. As gorges widen, the effect of shading diminishes.

Dominant Soils—Bouldin, Brookside, Shelocta, and Talbott. Formerly mapped as limestone rockland or bouldery colluvial land.

Bedrock—Limestone; occasionally siltstone and shale.

Depth to Bedrock—Mostly 60 in or more but may be 20 to 40 in where Talbott soils occur.

Texture—Channery to stony loam, sandy loam, silt loam, and silty clay loam.

Soil Drainage—Well-drained to moderately well-drained.

Relative Soil Water Supply—Low to very low. Usually soil water percolates deep into the limestone, but seeps and springs are associated with Brookside soils.

Soil Fertility—Moderate to moderately low.

Vegetation—White oak, scarlet oak, chestnut oak, hickories, eastern redcedar, white ash, post oak, black oak, and elms; occasional red maple, blackgum, black locust, hackberry, chinkapin oak, honeylocust, blue ash, American beech, Virginia pine, and shortleaf pine. Eastern redbud, dogwood, winged elm, viburnums, ironwood, hawthorns, and sumac are common in the understory.

Table 22.—*Forest management interpretations for Landtype 18: Lower escarpment slopes and benches—south aspect*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft^3/acre)
Shortleaf Pine	55	90
Virginia pine	60	53
E. redcedar	45	....
White oak	50	32

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Slight	Moderate to severe	Moderate to severe	Moderate to severe	Slight

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
Shortleaf pine	Hickories	Ironwood
Virginia pine	Post oak	American beech
E. redcedar	Chestnut oak	Winged elm
White oak	Chinkapin oak	Hackberry
White ash	Black oak	E. redbud
	Scarlet oak	Honeylocust
	Elms	Red maple
	Black locust	Blackgum
	Blue ash	Dogwood

See footnotes 1 and 2 to table 5, p. 25.

Description of Landtype 19:
Shallow Soils and Limestone Outcrops

Geographic Setting—Small to extensive areas of limestone outcrops interspersed with patches of shallow to moderately deep, clayey soils in Subregion 2. In LTA-C, this intricate pattern of soils and rock outcrops occurs in gorges of steams that have cut through the sandstone caprock and on footslopes of Plateau spur ridges bordering the Eastern Highland Rim and Pennyroyal in association with Landtypes 17 and 18. In LTA-D, Landtype 19 represents the intermittent limestone cliffs and bands of shallow soils immediately above these cliffs. Limestone or shale ridges (Landtypes 22, 6, or 2) and, in a few places, shale slopes (Landtypes 20 and 21) occur above the cliffs, and Landtypes 17 and 18 occupy the rocky colluvial slopes below the cliffs. Eastern redcedar often dominates this landtype. Slope ranges from 2 to 60 percent. The soil mass may contain up to 65 percent limestone slabs. More than 50 percent of the soil surface may be exposed limestone, and, where exposure is extensive, the limestone is often terraced. The intermittent cliffs in LTA-D are not quite vertical because of the regional dip to the southeast.

Dominant Soils—Barfield, Fairmount, Gladeville, and limestone rockland. Pockets of moderately deep Talbott, Colbert, and Caneyville may occur in this landtype.

Bedrock—Limestone and thin strata of calcareous clay shale.

Depth to Bedrock—Mostly less than 20 in but ranges up to 40 in where Talbott, Colbert, and Caneyville soils occur.

Texture—Silty clay loam, silty clay, and clay.

Soil Drainage—Well-drained to excessively drained, except for Colbert soils, which are moderately well-drained.

Relative Soil Water Supply—Low. Seepage is common in wet weather, but the soil dries quickly.

Soil Fertility—Moderate.

Vegetation—Eastern redcedar, hickories, blue ash, hackberry, white ash, and elms; occasional honeylocust, Virginia pine, blackjack oak, black walnut, butternut, yellow-poplar, southern red oak, and osage-orange. Forbs, grasses, sumac, eastern redbud, winged elm, Carolina buckthorn, rusty blackhaw, hawthorns, and pricklypear are common in the understory. Very small openings (<1 acre) of native grassland occur in this landtype. Little bluestem is dominant, while big bluestem, Indiangrass, side-oats grama, and other grasses and forbs are frequent constituents.

Table 23.—*Forest management interpretations for Landtype 19: Shallow soils and limestone outcrops*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft³/acre)
Virginia pine	(55)	41
E. redcedar	40	....
Upland oaks	(55)	38

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Slight	Severe	Moderate to severe	Moderate	Moderate to severe

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
Virginia pine E. redcedar	Black walnut Butternut Hickories S. red oak Elms Yellow-poplar White ash Blue ash	Blackjack oak Winged elm Hackberry Osage-orange E. redbud Honeylocust

See footnotes 1 and 2 to table 5, p. 25.

Description of Landtype 20:
Colluvial Siltstone Slopes—North Aspect

Geographic Setting—Deep, loamy, and gravelly soils on sloping to very steep lower two-thirds to three-fourths of north slopes west of the Plateau sandstone free face in LTA-D, Subregion 2. The linear to convex sideslopes and concave toeslopes range from 2 to 60 percent but are dominantly greater than 12 percent. Soils formed in coarse, loamy colluvium washed from acid siltstone and shale of lower Mississippian origin. Landtype 20 occurs below shale ridges (Landtypes 2 and 6) and above terraces, streambottoms, and flood plains (Landtypes 12 and 13 or 23 and 24). In places, Landtype 20 occurs between shale ridges and limestone cliffs (Landtype 19).

Dominant Soil—Cranston.

Bedrock—Siltstone and shale.

Depth to Bedrock—4 to 20 ft.

Texture—Gravelly silt loam. The weighted average of pebbles and channers of acid siltstone in the control section is less than 35 percent by volume but may range up to 60 percent in the A and C horizons and up to 45 percent in the B horizon.

Soil Drainage—Well-drained.

Relative Soil Water Supply—Medium to high.

Soil Fertility—Moderate.

Vegetation—White oak, scarlet oak, black oak, and hickories; occasional chestnut oak, shortleaf pine, American beech, cucumbertree, yellow-poplar, northern red oak, white ash, southern red oak, blackgum, red maple, and black locust. Dogwood, sassafras, serviceberry, sourwood, and smilax are common understory species.

Table 24.—*Forest management interpretations for Landtype 20: Colluvial shale slopes—north aspect*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft^3/acre)
N. red oak	80	62
Yellow-poplar	90	90

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Severe	Slight	Moderate to severe	Moderate to severe	Slight

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
White oak	Shortleaf pine	American beech
N. red oak	Hickories	Sassafras
Yellow-poplar	Chestnut oak	Black locust
White ash	Black oak	Red maple
	S. red oak	Blackgum
	Scarlet oak	Dogwood
	Cucumbertree	Sourwood

See footnotes 1 and 2 to table 5, p. 25.

Description of Landtype 21:
Colluvial Siltstone Slopes—South Aspect

Geographic Setting—Deep, loamy, and gravelly soils on sloping to very steep lower two-thirds to three-fourths of south slopes west of the Plateau sandstone free face in LTA-D, Subregion 2. The linear to convex sideslopes and concave toeslopes range from 2 to 60 percent but are dominantly greater than 12 percent. Soils formed in coarse, loamy colluvium washed from acid siltstone and shale of lower Mississippian origin. Landtype 21 occurs below shale ridges (Landtypes 2 and 6) and above terraces, streambottoms, and flood plains (Landtypes 12 and 13 or 23 and 24). In places, Landtype 20 occurs between shale ridges and limestone cliffs (Landtype 19).

Dominant Soil—Cranston.

Bedrock—Siltstone and shale.

Depth to Bedrock—4 to 20 ft.

Texture—Gravelly silt loam. The weighted average of pebbles and channers of acid siltstone in the control section is less than 35 percent by volume but may range up to 60 percent in the A and C horizons and up to 45 percent in the B horizon.

Soil Drainage—Well-drained.

Relative Soil Water Supply—Medium.

Soil Fertility—Moderate.

Vegetation—White oak, scarlet oak, chestnut oak, shortleaf pine, and hickories; occasional red maple, northern red oak, scarlet oak, black oak, blackgum, and black locust. Sassafras, dogwood, sourwood, serviceberry, and smilax are common understory species.

Table 25.—*Forest management interpretations for Landtype 21: Colluvial shale slopes—south aspect*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft^3/acre)
Shortleaf pine	70	125
Scarlet oak	70	52

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Moderate	Moderate	Moderate to severe	Moderate to severe	Slight

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
Shortleaf pine	Hickories	Sassafras
White oak	Black locust	Red maple
Chestnut oak	N. red oak	Blackgum
Black oak		Dogwood
S. red oak		Sourwood

See footnotes 1 and 2 to table 5, p. 25.

Description of Landtype 22:
Limestone Ridges and Convex Upper Slopes

Geographic Setting—Moderately deep to deep, silty and clayey soils on gently sloping to steep, narrow to modertely broad crests and convex upper slopes of hills and ridges in Subregion 2. Slope ranges up to 60 percent but is dominantly les than 30 percent; aspect does not seem to be an important site factor. Width of ridges range from 300 to 500 ft. Landtype 22 occurs occasionally in LTA-C and in the northwestern part of LTA-D adjacent to and sometimes intermingled with shallow soils and limestone outcrops (Landtype 19). Colluvial limestone slopes (Landtypes 17 and 18) occur below Landtype 22 in both landtype associations. In LTA-D, Landtype 22 is often bounded by limestone scliffs (Landtype 19), and shale ridges (Landtypes 2 or 6) may project above the general level of the limestone uplands. Sinkholes occur in places.

Dominant Soil—Caneyville and Hagerstown.

Bedrock—Limestone.

Depth to Bedrock—20 in to more than 4 ft but mostly less than 40 in.

Texture—Loam, silt loam, and silty clay loam; rock content is less than 15 percent.

Soil Drainage—Well-drained.

Relative Soil Water Supply—Medium. Deep percolation in karst areas.

Soil Fertility—Moderate.

Vegetation—White oak, southern red oak, black oak, hickories, blackgum, and shortleaf pine; occasional scarlet ocak, northern red oak, chestnut oak, elms, red maple, Virginia pine, yellow-poplar, black walnut, and white ash. Dogwood, sourwood, eastern hophornbeam, winged elm, sassafras, vacciniums, wild plum, persimmon, and eastern redbud are common understory species.

Table 26.—*Forest management interpretations for Landtype 22: Limestone ridges and convex upper slopes*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft^3/acre)
E. redcedar	45	....
N. red oak	75	52–57
Black oak	75	
Scarlet oak	70	
Yellow-poplar	85	80

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Slight to moderate	Slight to moderate	Moderate to severe	Moderate to severe	Slight

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
Shortleaf pine	Virginia pine	E. hophornbeam
Black walnut	Hickories	Winged elm
White oak	Chestnut oak	Sassafras
N. red oak	Black oak	E. redbud
Yellow-poplar	S. red oak	Red maple
White ash	Scarlet oak	Blackgum
	Elms	Dogwood
		Sourwood
		Persimmon

See footnotes 1 and 2 to table 5, p. 25.

Description of Landtype 23: Footslopes, Terraces, and Flood Plains with Good Drainage

Geographic Setting—Deep, loamy, and silty alluvial soils with good internal drainage on level to strongly sloping footslopes, terraces, and flood plains along the Cumberland and Kentucky Rivers and their major tributaries in Subregion 3. Slope ranges from 0 to 20 percent on footslopes and terraces but is 5 percent or less on flood plains. This landtype occurs in association with Landtype 24, which has poor internal drainage.

Dominant Soils—Allegheny, Monongahela, Cotaco, Captina, and Elk on footslopes and terraces; Cuba, Steff, Pope, Philo, Huntington, Lindside, and Combs on floor plains.

Parent Material—On terraces, soils formed in old silty alluvium, and on flood plains, parent material consists of more recent alluvium. Alluvium washed from soils formed in residuum or colluvium weathered from acid sandstone, siltstone, shale, and limestone.

Depth to Bedrock—3½ to more than 10 ft. Monongahela and Captina soils have fragipans at depths ranging from 18 to 30 in and 16 to 30 in, respectively.

Texture—Silt loam, loam, and fine sandy loam; occasionally sandy loam and silty clay loam. Solums usually contain less than 35 percent rock fragments. C horizons may contain more than 35 percent rock fragments or lenses of gravel. In Captina soils, the lower part of the fragipan may contain up to 75 percent chert fragments.

Soil Drainage—Well-drained to moderately well-drained.

Relative Soil Water Supply—High. Low areas flood occasionally.

Soil Fertility—Moderately high to high.

Vegetation—White oak, sweetgum, yellow-poplar, blackgum, elms, red maple, northern red oak, river birch, and hickories; occasional American beech, black willow, pin oak, boxelder, black oak, American sycamore, black walnut, silver maple, southern red oak, shingle oak, sourwood, eastern hemlock, Virginia pine, shortleaf pine, eastern white pine, persimmon, and sassafras. Dogwoods, eastern redbud, eastern hophornbeam, American hornbeam, cane, viburnums, American hazel, sumacs, and elderberry are common understory species.

Table 27.—*Forest management interpretations for Landtype 23: Footslopes, terraces, and flood plains with good drainage*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft^3/acre)
E. white pine	85	145
Shortleaf pine	75	136
Virginia pine	75	120
Northern red oak	80	62
Yellow-poplar	95	98
Sweetgum	90	81
Sycamore	(90)	....

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Moderate to severe	Slight	Slight to moderate	Slight to moderate	Slight

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
E. white pine	Hickories	E. hemlock
Shortleaf pine	American beech	River birch
Virginia pine	Black oak	American hornbeam
Black walnut	Southern red oak	E. hophornbeam
White oak	Shingle oak	Sassafras
N. red oak	Elms	American hazel
Pin oak		E. redbud
Yellow-poplar		Sumacs
Sweetgum		Red maple
American sycamore		Boxelder
		Blackgum
		Dogwoods
		Sourwood
		Persimmon

See footnotes 1 and 2 to table 5, p. 25.

Description of Landtype 24:
Terraces and Flood Plains with Poor Drainage

Geographic Setting—Deep, loamy, and silty alluvial soils with poor internal drainage on level to gently sloping terraces and flood plains along the Cumberland and Kentucky Rivers and their major tributaries in Subregion 3. Slope is 4 percent or less. This landtype occurs in association with Landtype 23, which has good internal drainage.

Dominant Soils—Morehead on terraces; Stendal, Atkins, Stokly, Melvin, and Newark on flood plains.

Parent Material—On terraces, soils formed in old silty alluvium, and on flood plains, parent material consists of more recent alluvium. Alluvium washed from soils formed in residuum or colluvium weathered from acid sandstone, siltstone, shale, and limestone.

Depth to Bedrock—5 to 10 ft or more.

Texture—Silt loam, loam, and silty clay loam; occasionally sandy loam and fine sandy loam. Coarse fragment content is usually less than 20 percent in the solum but may range up to 60 percent below 40 in.

Soil Drainage—Somewhat poorly drained and poorly drained.

Relative Soil Water Supply—High to very high. A fluctuating water table is near the surface part of the time, and the landtype is subject to occasional flooding.

Soil Fertility—Moderately high to high.

Vegetation—Pin oak, sweetgum, swamp white oak, red maple, green ash, elms, and blackgum; occasional American sycamore, silver maple, shagbark hickory, shellbark hickory, river birch, yellow-poplar, black willow, hackberry, boxelder, and cottonwood. Dogwoods, cane, grasses, sedges, ferns, alder, common poison-ivy, and common trumpet-creeper are common in the understory.

Table 28.—*Forest management interpretations for Landtype 24: Terraces and flood plains with poor drainage*

PRODUCTIVITY

Species	Site index[1]	Average annual growth[2] (ft^3/acre)
Yellow-poplar	90	90
Sweetgum	90	81
Pin oak	95	....

MANAGEMENT PROBLEMS

Plant competition	Seedling mortality	Equipment limitations	Erosion hazard	Windthrow hazard
Moderate to severe	Moderate to severe	Moderate to severe	Slight	Slight

SPECIES DESIRABILITY

Most desirable	Acceptable	Least desirable
E. cottonwood	Shagbark hickory	Black willow
Swamp white oak	Shellbark hickory	River birch
Pin oak	Elms	Silver maple
Yellow-poplar	Hackberry	Boxelder
Sweetgum	Red maple	Blackgum
American sycamore		Dogwoods
Green ash		

See footnotes 1 and 2 to table 5, p. 25.

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APPENDIX

COUNTY SOIL SURVEYS AVAILABLE FOR THE NORTHERN CUMBERLAND PLATEAU

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METRIC EQUIVALENTS

1 inch = 2.54 centimeters (exactly)

1 foot = 0.3048 meter (exactly)

1 acre = 0.4047 hectare

1 square foot/acre = 0.2296 square meter/hectare

1 cubic foot/acre = 0.06997 cubic meter/hectare

1 mile = 1.6093 kilometers

1 square mile = 2.5900 square kilometers

°C = (°F-32)/1.8

Smalley, Glendon W. 1986 Classification and evaluation of forest sites on the Northern Cumberland Plateau. U.S. Dep. Agric. For. Serv. Gen. Tech. Rep. SO-60. 74 p.

Presents a comprehensive forest site classification system for the Northern Cumberland Plateau in north-central Tennessee and eastern Kentucky. The system is based on physiography, geology, soils, topography, and vegetation.

Additional keywords: Site index, mean annual increment, soil properties, pines, hardwoods.

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Net Community Production Dynamics in the Herb-Shrub Stratum of a Loblolly Pine-Hardwood Forest: Effects of Clearcutting and Site Preparation

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SUMMARY

Prior to clearcutting, the forest contained few herbaceous species, and net community production (NCP) of the herb-shrub stratum (vegetation below 1.5 m height) was low. Removal of overstory trees by clearcutting increased the number of herb species and NCP of herbs and woody plants. Burn, chop, and KG blade site preparations further increased species numbers, NCP, and relative frequency (RFR) of herbs, while mechanical site treatments temporarily reduced the number, NCP, and RFR of woody plants. As planted pines and residual hardwood trees grew taller and the canopy closed, the number of herb species and their NCP and RFR gradually decreased. The number of woody plant species did not decrease, but their NCP decreased and their RFR increased. Some herbaceous and woody species that were absent or low in frequency in the uncut forest occurred with high frequencies after site preparation but disappeared again in subsequent years.

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INTRODUCTION

Clearcutting of forests and site preparation greatly fluence the species composition and net community oduction (NCP) of herbaceous and woody plants. ch even-aged silvicultural systems play an imrtant role in intensive forest management of south- n pines and are widely used. These practices have e potential to drastically change the forest vironment.

The clearcutting system that produces even-aged rest stands has both proponents and opponents. Ac- rding to Meyer and others (1961), the proponents int out that: (1) the silviculture of shade intolerant ecies requires even-aged management, (2) the plan- ng and execution of timber harvesting operations is ore efficient, and (3) the costs are lower for marking, and improvement, inventory, protection, road con- ruction, aids to regeneration, logging, and general pervision. Therefore, even-aged management pro- ces the greatest timber volume in the shortest time. n the other hand, opponents of the even-aged system ain that uneven-aged forest systems work better for tolerant species because they: (1) provide higher oduction of larger and presumably more valuable ees (2) maintain all areas of the forest under contin- us active production, (3) can more profitably meet anging market requirements by flexible volume gulation, and (4) can overcome calamities with less onomic loss.

Similar comparisons are offered by Troup (1952) d by Köstler (1950), based mostly on European ex- rience. Both authors conclude that clearcutting has eat advantages if applied under suitable soil and pographic conditions. In the loblolly pine (*Pinus* *eda*-shortleaf (*P. echinata*) pine-hardwood forests east Texas, unpublished data from several long- rm studies showed that adequate pine regeneration as consistently obtainable only with clearcutting, e preparation, and planting.

Considerable information exists on the effects of clearcutting and site preparation on pine seedling survival and growth. However, fewer references are available about their effects on herbs and woody plants in the herb-shrub stratum of the forest understory. Most plant successional studies have documented plant succession on abandoned agricultural land rather than on disturbed forest land.

Shrubs, trees, and woody vines in the open grew twigs that were seven times longer than twigs on plants beneath a sawtimber stand of pines (Halls and Alcaniz, 1968). Studies by Schuster and Halls (1963), Schuster (1967), Blair (1971), and Blair and Brunett (1976) showed the relationship of overstory density to NCP in the herb stratum. However, these studies did not consider the influence of site preparation.

Site preparation improves survival of planted pine seedlings by reducing competition for available soil moisture (Stransky 1961). This is especially important in east Texas, the western edge of the southern pine belt, because summer droughts frequently occur and result in considerable seedling mortality. Also, site preparation increases seedling growth for many years (Wagenknecht 1941, Stransky 1964, Schultz 1975).

All site preparation methods are designed to eliminate or retard woody plants that compete with the planted pines for growing space. In Alabama, Carter and others (1975) noted that many of the woody plants escaped injury, recovered, or resprouted after chemical site treatment. Intensive mechanical treatments were more effective in eliminating woody plants, and some woody species were absent in the next rotation.

In east Texas, herbaceous plants quickly occupied the cleared area during the first growing season after clearcutting and site preparation by chopping and burning (Stransky and others 1974). Sixty-eight percent of the recorded 105 herbaceous species grew only in cleared areas.

In the west Florida Sandhills, Burns and Hebb

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(1972) noted that mechanically prepared sites were rapidly colonized by herbaceous and woody plants. Chopped sites were first dominated by members of the composite family. Twelve years after chopping, Hebb (1971) distinguished four stages of succession: (1) the denuded site, (2) the profusion of forbs, (3) the dominance of a few species, and, eventually, (4) the shading out of the ground cover by the overstory of planted pines.

Also in Florida, White and others (1976) reported the impact of clearcutting and site preparing on the aboveground mass of herbs and woody plants 9 years after treatment. The site preparation intensities and treatments were: (1) low—burn; (2) medium—burn, KG blade, shear, and harrow; and (3) high—burn, KG blade, harrow, and bed (mounding of the planting row). Herbage mass was inversely related to site treatment intensity. Woody plants, including planted pines, grew best under the medium- and high-intensity treatments.

The effect of fire on vegetation and sites are enumerated by Odum and others (1973) as follows: (1) plant species characteristic of earlier stages return to dominance, (2) net primary production increases, (3) species diversity decreases, and (4) the inorganic mineral pool in living plants increases, at least temporarily, as nutrients are released from the organic detritus pool. The authors also observed that plant succession following fire was rapid.

Early stages of plant succession following logging and burning in Oregon indicated similar trends (Dyrness 1973). Invading herbaceous species dominated from the second through the fourth growing season after burning. By the fifth year residual herbaceous species regained dominance. In east Texas, Lay (1956) recorded that NCP of yaupon (*Ilex vomitoria*) diminished after fire; however, NCP of other woody plants increased. The increase of legumes after fire was reported by Cushwa and others (1970) and by Komarek (1974).

The objectives of this study were to explore how clearcutting, site preparation, and planting of pine on a loblolly pine-hardwood forest site affect species numbers, species composition, and NCP in the herb-shrub stratum of the developing new forest stand.

STUDY AREA

The study area near Jasper, Texas, is part of the loblolly-shortleaf pine-hardwood forest type that covers approximately 28 million ha in the southeastern and southern United States, reaching its westernmost limit in east Texas. The area was never cleared for agriculture but may have been grazed by cattle.

The area is part of the Gulf Coastal Plain Quaternary deposits, underlain by sands, sandstones, and clays of the Oligocene period (Dumble 1918). S
belong to the Bernaldo-Elysian complex and to
Sacul series. The moundy Bernaldo-Elysian soils
cur in such patterns that separation is diffic
Bernaldo soils (Glossic Paleudalfs, fine-loar
siliceous, thermic family), constitute the lower par
the mounds and most of the adjoining low areas. T
comprise about 50 percent of the area. Elysian s
(Haplic Glossudalfs, coarse-loamy, siliceous, ther
family) occupy the upper part of the mounds
make up about 40 percent of the area. The major
ference between these soils is that the Elysian ha
sandy surface layer more than 50 cm thick, while
Bernaldo has a thinner layer. With slopes rang
from 0 to 3 percent, these well-drained, modera
permeable soils have slow surface runoff. Sacul s
(Aquic Hapludalfs, clayey, mixed thermic family)
found at the drainage heads of and normally are a
ciated with concave topography. They occupy sl
from 1 to 6 percent, are moderately well-drained,
have slow permeability (U.S. Department of Agri
ture 1975).

The region has hot humid summers, mild wint
and a growing season of about 230 days. Annual r
fall averages 129 cm (U.S. Department of Comm
1965). However, in 1972, 1973, and 1974, rainfall
137, 218, and 178 cm. Such high precipitation o
interfered with site preparation, burning, and pl
ing schedules.

Prior to clearcutting, the site supported a saw
ber stand of pines and hardwoods. Average age o
forest stand was 45 years.

METHODS

The forest was clearcut and the merchantable
ber removed in September 1972. The following
preparation treatments were applied to 0.6 ha plo
a randomized block design with three replicatio

Control—no site preparation, but all remai
nonmerchantable woody stems greater
2.5 cm d.b.h. (diameter at breast height) wer
and left in place in the winter of 1972-73.

Burn—all stems larger than 2.5 cm d.b.h. wer
(as in control) and burned with the logging
on 6 March 1974. Spread by winds of a
20 km/hr, the headfire consumed the tops
remaining herbaceous plants, most shrubs,
trees, nearly all leaf litter, and all but the la
branches of the logging slash.

Chop—logging slash and all stems were cut v
16,000 kg chopper in October 1972, and aga
October 1973. The chopper resembles a
lawn roller equipped with cutting blades pa

to the long axis of the cylinder. Pulled by a D-8 crawler tractor, the chopper cut nonmerchantable trees and shrubs into 50-cm lengths and crushed much of the debris into the surface soil. The chopped plots were burned on 6 and 7 March 1974, but the fire was spotty and of low intensity.

KG blade—all stems were cut with a KG blade in November 1973 and the logging slash was raked off the plots into windrows that were burned on 6 March 1974. The KG blade has a heavy cutting edge mounted at an angle on the front of a large crawler tractor. The blade sheared off all stems approximately at ground line. The cutting and raking process disturbed the soil surface and pushed some litter and topsoil off the planting site into the windrows.

Due to rainy weather, only the chop treatment was ompleted in 1972. All site preparation treatments ere completed one growing season after clearcutting uring the 1973–74 fall-winter period. The chopped lots were rechopped in 1973. All plots were hand-lanted with 1-0 (one-year-old nursery-grown) blolly pine seedlings at 2.4- by 3.0-m spacings in id-March 1974.

Vegetation inventories were conducted prior to earcutting (July 1972); one growing season after earcutting (August 1973); and one (August 1974), ree (July 1976), five (July 1978), eight (July 1981), nd ten (June 1983) growing seasons after site prepa-tion. Samples from the herb-shrub stratum (all ants, except the planted pines from ground level to 5 m height) were collected from twenty 1.01 m^2 uadrats evenly spaced at 11.1 by 11.1 m within the ntral two-thirds of each plot. Sample quadrats were fset from the permanently marked sample points to void areas where prior samples had been collected.

Annual NCP was determined by the harvest ethod. The current growing season's new growth of rbaceous and woody plants was clipped from ground vel to 1.5-m height. Although rooted outside the mple quadrat, plant parts that projected into the mple space were harvested also (Daubenmire 1968). ippings were separated into 10 plant groups, oven-ied at 70 °C, and weighed (Stransky 1976). The ant groups were: grasses, grasslikes, legumes, com-sites, other forbs, vines, shrubs, pines, oaks, and her trees. The NCP for species or genus (as in *nicum*, *Carex*, *Rubus*, or *Crataegus* spp.) was com-ited by visually estimating the percentage of the tal weight that individual species or genus com-sed within each plant group. This percentage was ultiplied times the actual total ovendry weight of at group. Both NCP and frequency were computed r species or genera. Relative frequency (RFR) was mputed by plant group only. Plant nomenclature follows the "Manual of the Vascular Plants of Texas" (Correll and Johnston 1970).

Differences in NCP in kg/ha/yr of herbs, woody plants, and total plants between consecutive years were compared by analysis of variance within each site preparation treatment. All testing was at the 0.05 level of probability.

RESULTS AND DISCUSSION

Before Clearcutting

The uncut forest consisted mainly of loblolly pine interspersed with shortleaf pine, sweetgum (*Liquidambar styraciflua*), blackgum (*Nyssa sylvatica*), red maple (*Acer rubrum*), southern red oak (*Quercus falcata*), water oak (*Q. nigra*), post oak (*Q. stellata*), hickories (*Carya* spp.), hawthorns (*Crataegus* spp.), American holly (*Ilex opaca*), and sassafras (*Sassafras albidum*). Major understory trees and shrubs were American beautyberry (*Callicarpa americana*), flowering dogwood (*Cornus florida*), yaupon, southern waxmyrtle (*Myrica cerifera*), blackberry (*Rubus* spp.), blueberry (*Vaccinium* spp.), and Sebastian bush (*Sebastiania fruticosa*). Prominent vines were yellow jessamine (*Gelsemium sempervirens*), Alabama supplejack (*Berchemia scandens*), poison ivy (*Rhus toxicodendron*), Virginia creeper (*Parthenocissus quinquefolia*), muscadine grape (*Vitis rotundifolia*), and greenbriers (*Smilax* spp.).

Few herbaceous species grew under the dense tree canopy (fig. 1). Panic grasses (*Panicum* spp.), chasmanthium (*Chasmanthium sessiliflorum*), sedges (*Carex* spp.), downy milkpea (*Galactia volubilis*), tobacco-weed (*Elephantopus tomentosus*), goldenrod (*Solidago* spp.), copperleaf (*Acalypha* spp.), twin-eyed berry (*Mitchella repens*), and noseburn (*Tragia urens*) were most prominent.

Annual NCP was low under the dense forest overstory for both herbaceous and woody species (fig. 2). This corroborates the findings by Schuster and Halls (1963), and Schuster (1967), that showed fewer species and less NCP under dense forest canopies than in open forest stands. Chasmanthium, tobacco-weed, and two-eyed berry composed most of the NCP of herbaceous plants. Among woody plants, shrubs contributed most to NCP, and their RFR was highest (figs. 2 and 3). Net community production and RFR of legumes and pines is not shown in figures 2 and 3 because both plant groups occurred at low levels not noticeable on the scale of the graphs. Herbs contributed 14 percent and woody plants 86 percent of the total NCP (359 kg/ha) in the herb-shrub stratum. Total NCP, the relative NCP, and RFR of herbs and woody plants were similar on all areas prior to clearcutting (table 1).

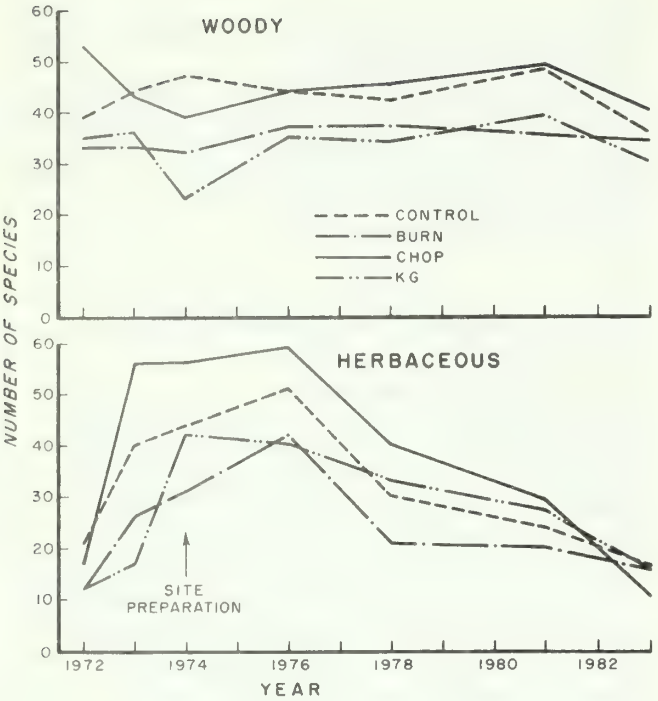

Figure 1.—*Number of plant species in the herb-shrub stratum of a loblolly pine-hardwood forest before (1972) and after (1973) clearcutting, and one (1974), three (1976), five (1978), eight (1981), and ten (1983) growing seasons after four methods of site preparation.*

After Clearcutting

By August 1973, one growing season after clearcutting, the number of herbaceous species had more than doubled (fig. 1) and had increased on most of the plots that had been chopped in October 1972. On the plots destined to be KG bladed, standing cull hardwoods and small pines suppressed herb species the first growing season after clearcutting. Composites and other forbs increased greatly and now averaged 74 percent of all herbaceous species. New species that appeared after the cut were horse-weed (*Conyza canadensis*), boneset (*Eupatorium* spp.), Canada lettuce (*Lactuca canadensis*), and polypremum (*Polypremum procumbens*) (table 2). The frequency of chasmanthium declined, while that of panicum increased.

The number of woody species decreased only on the chopped plots (fig. 1). On the other areas, the number of woody species remained the same or increased slightly. Other trees, shrubs, and vines made up 87 percent of all woody species. Frequency of American beautyberry, blackberry, and St. Peter's-wort (*Ascyrum* spp.) greatly increased (table 2).

During the first growing season after clearcutting, grasses increased most quickly in response to overstory removal. Net community production and RFR of all herbs showed the greatest increase on the plots chopped in 1972 (fig. 2, table 1). Herb NCP and RFR increase on the other plots were suppressed by numerous unharvested hardwoods and dense tangles of shrubs and vines.

Woody NCP peaked on the controls the first year after overstory removal (fig. 2). Net community production increased to a lesser degree on the plots to be burned or KG bladed. The NCP increase of oaks and other trees, and also their RFR, was less on chopped than on other plots (figs. 2 and 3). On all treatments, the NCP of shrubs showed the greatest response to complete or partial overstory removal (fig. 2). Halls and Alcaniz (1968) found that NCP of shrubs and vines in the open was greater than under the shade of a forest canopy and increased with partial overstory removal (Blair and Brunett 1976). Relative NCP of herbs increased to 32 percent and of woody plants dropped to 68 percent (table 1).

First Year After Site Preparation

Approximately one growing season after site preparation (August 1974), the number of herbaceous species further increased with all site treatments. The NCP and RFR increased most among grasses, composites, and other forbs. All treatments greatly increased the frequency of Canada lettuce and polypremum. The mechanical disturbance caused by chop or KG blading increased the frequency of horse-weed and boneset (table 2).

Such rapid colonization by herbs of clearcut and site-prepared areas has also been reported by Hebb (1971), Burns and Hebb (1972), Stransky and others (1974), Stransky (1976), and White and others (1975). Burning of the planting site created conditions similar to those described by Odum and others (1974), and Dyrness (1973).

The number of woody species and their RFR declined with chopping and even more with KG blading (figs. 1 and 3). The frequency of some shrubs, vines, and trees decreased after KG blading and decreased to a lesser degree after chopping (table 2).

Herbaceous and woody plant species found on the study site are characteristic of the east Texas Piney Woods, and have been enumerated by Schuster (1967), Stransky and others (1974), and Stransky (1976). During the course of this study, the distribution of the 124 herbaceous and 77 woody plants that were identified to species or genus follows: 14 grasses, 8 grasslikes (sedges and rushes), 15 legumes, 40 composites, 47 other forbs (representing 22 families), 28 shrubs (18 families), 17 vines (7 families), 2 pines, 9 oaks, and 21 other trees (16 families).

Of the total herbaceous NCP, composites and other forbs made up 73 percent, with the remainder being mostly grasses (fig. 2). Some species and genera experienced their greatest NCP and frequency during the first growing season after site treatments; for exam

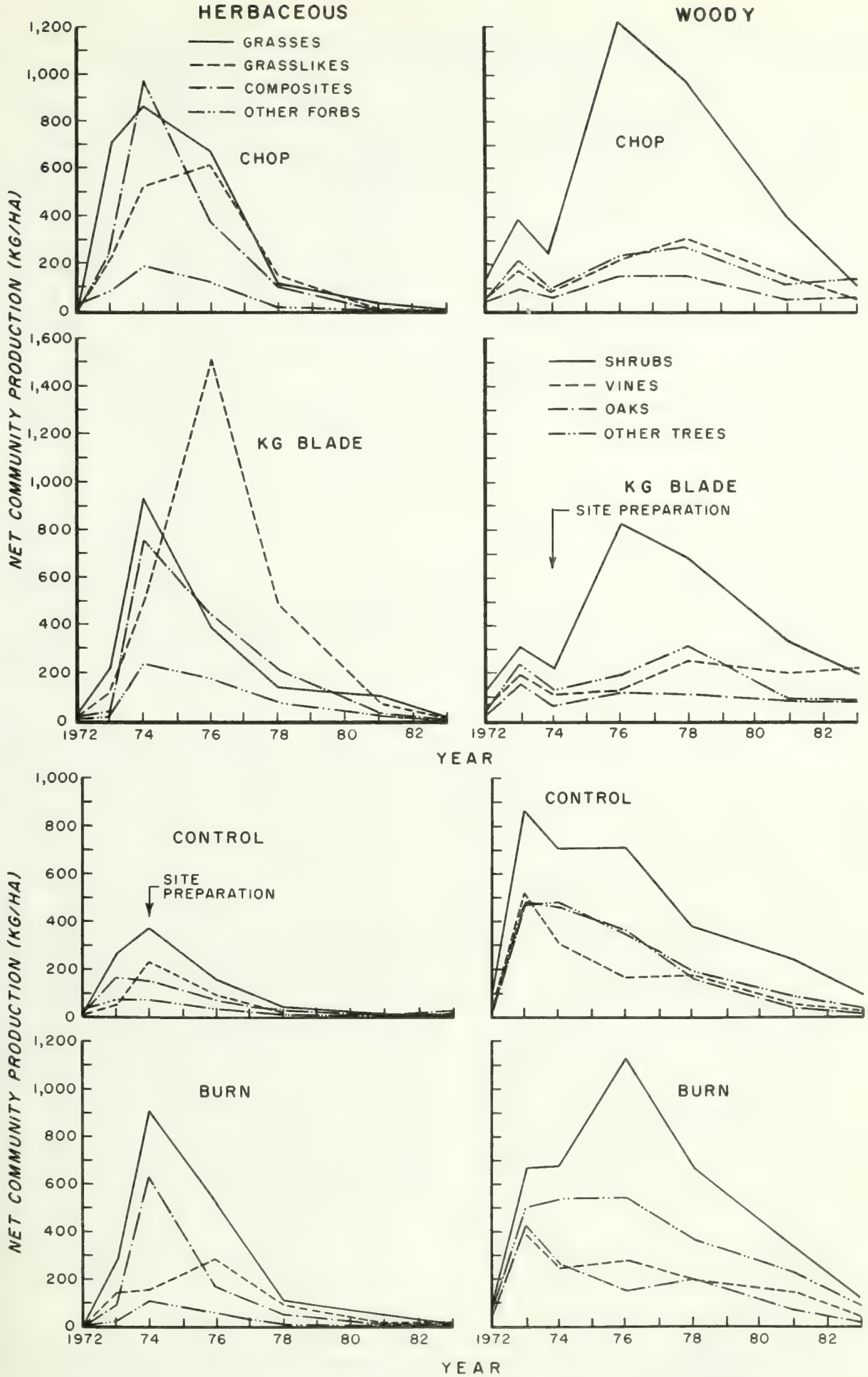

Figure 2.—*Annual net community production (kg/ha) of plant groups in the herb-shrub stratum of a loblolly pine-hardwood forest before (1972) and after (1973) clearcutting, and one (1974), three (1976), five (1978), eight (1981), and ten (1983) growing seasons after four methods of site preparation.*

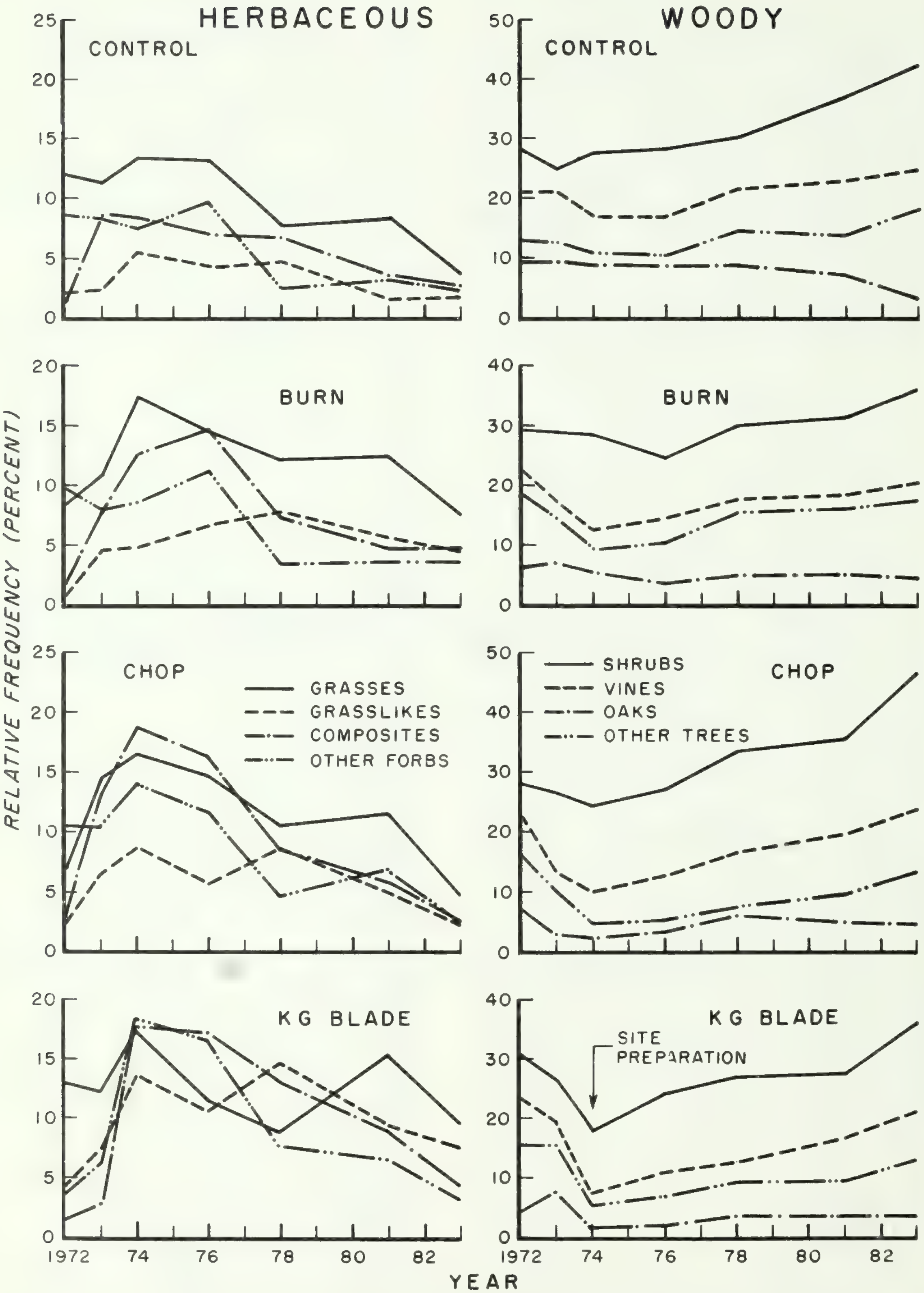

Figure 3.—*Relative frequency (percent) of plant groups in the herb-shrub stratum of a loblolly pine-hardwood forest before (1972) and after (1973) clearcutting, and one (1974), three (1976), five (1978), eight (1981), and ten (1983) growing seasons after four methods of site preparation.*

Table 1.—*Net community production, relative net community production, and relative frequency of herbaceous and woody plants in the herb-shrub stratum of a loblolly pine-hardwood forest before (1972) and after (1973) clearcutting, and one (1974), three (1976), five (1978), eight (1981), and ten (1983) growing seasons after four methods of site preparation*

Site preparation	Year	Net community production			Relative Net community production		Relative frequency	
		Herb	Woody	Total	Herb	Woody	Herb	Woody
		kg/ha			*percent*		*percent*	
Control	1972	73	309	382	19	81	25.0	75.0
	1973	560*	2355*	2915*	19	81	31.0	69.0
	1974	830	1957	2787	30	70	35.0	64.9
	1976	370*	1613	1983*	19	81	34.9	65.1
	1978	95*	919	1014*	9	91	22.3	77.7
	1981	26	427	453	6	94	17.9	82.1
	1983	28	175	203	14	86	11.3	88.7
Burn	1972	22	340	362	6	94	22.2	77.8
	1973	524*	2007*	2531*	21	79	31.9	68.1
	1974	1803*	1737	3540	51	49	43.9	56.0
	1976	1029*	2098	3127	33	67	47.2	52.0
	1978	254*	1429*	1683*	15	85	30.5	69.5
	1981	72*	771*	843*	9	91	27.1	72.8
	1983	19	268	287	7	93	21.0	79.0
Chop	1972	59	324	383	15	85	23.5	76.5
	1973	1256*	877*	2133	59	41	45.9	54.1
	1974	2555*	498*	3053*	84	16	58.9	41.1
	1976	1795*	1824*	3619*	49	51	51.3	48.7
	1978	389*	1774	2163*	18	82	33.9	66.2
	1981	83*	732*	815*	10	90	30.0	69.8
	1983	10	372	382	3	97	11.5	88.4
KG Blade	1972	44	265	309	14	86	23.1	76.9
	1973	375	911	1286*	29	71	29.7	70.4
	1974	2411*	522*	2933*	82	18	67.0	33.0
	1976	2507	1267*	3774*	66	34	55.9	44.0
	1978	906	1392	2298	39	61	45.3	54.7
	1981	222*	707*	929*	24	76	40.5	59.5
	1983	43	619	662	7	93	25.0	74.9

*Significantly different from previous year's net community production at 0.05 percent level.

ple panic grasses, polypremum, horse-weed, and Canada lettuce; while the shade-tolerant chasmanthium showed little if any increase (table 2). The mechanical and burn treatments favored grasses and composites. The NCP of all herbaceous plant groups was smaller on the control plots than on the other treatments (fig. 2, table 1).

Woody NCP began to decline on the control plots this first year after site preparation. Burn plots showed a small increase in shrubs and other trees, but production of vines and oaks dropped. Mechanical site treatments noticeably reduced NCP and RFR of all woody plant groups (figs. 2 and 3, and table 1).

Third Year After Site Preparation

By July 1976, the number of herbaceous species peaked on all but the KG blading treatment, on which species richness decreased. The RFR of herbs began to decline on all treatments. Frequency of horse-weed, Canada lettuce, and polypremum declined drastically from previously sampled peaks (table 2). It is possible that one-generation seral species may owe their brief tenure to the accumulation of autotoxic substances (Daubenmire 1968). Strong evidence for autotoxin accumulation has been presented for horse-weed in abandoned-field succession in the North Carolina Piedmont (Keever 1950).

The number of woody species was close to pretreatment levels (fig. 1). The return to the stable original pretreatment number was especially noticeable on the mechanically treated plots that had experienced a substantial drop after the treatments were applied. The RFR of woody species was increasing. This increase was slower on the KG blading than on the other treatments.

Herbaceous total NCP decreased with all site treatments except KG blading. The NCP of grasslike species peaked on all but the control plots. Panic grasses decreased on most treatments, while shade-tolerant

Table 2.—*Frequency (percent) of common plants in the herb-shrub stratum of a loblolly pine-hardwood forest before (1972) and after (1973) clearcutting, and one (1974), three (1976), five (1978), eight (1981), and ten (1983) growing seasons after four-methods of site preparation*

Species or genus	Site preparation method																											
	Control							Burn							Chop							KG						
	1972	73	74	76	78	81	83	72	73	74	76	78	81	83	72	73	74	76	78	81	83	72	73	74	76	78	81	83
Liquidambar styraciflua	30	37	40	38	37	32	35	28	35	35	45	47	55	47	22	23	10	17	25	23	15	25	43	22	20	30	35	35
Nyssa sylvatica	12	30	22	23	17	15	10	25	33	35	47	42	50	27	15	22	10	12	17	20	20	23	27	17	27	30	25	32
Quercus falcata	13	37	30	30	22	10	5	10	15	15	15	7	12	10	12	13	5	15	15	20	5	10	28	5	7	10	10	7
Ilex vomitoria	28	17	18	33	38	48	52	33	35	12	7	15	17	40	42	30	23	42	48	55	48	35	28	7	20	20	27	32
Myrica cerifera	22	30	28	40	40	48	40	15	27	35	52	60	62	55	15	13	12	22	22	23	28	18	17	12	25	40	40	40
Sehastiania fruticosa	23	18	18	20	15	23	13	18	7	27	30	20	25	27	7	0	5	0	8	7	8	18	17	22	7	12	20	20
Callicarpa americana	30	47	48	47	28	45	38	28	50	50	47	35	30	35	20	45	50	63	52	68	57	13	22	10	27	15	22	30
Vaccinium spp.	27	27	40	38	33	37	22	22	25	27	32	15	15	12	38	30	27	32	28	22	17	30	28	17	27	35	22	22
Ascyrum spp.	8	13	18	3	7	5	2	5	20	20	10	2	12	10	8	43	47	27	3	10	3	8	10	52	15	12	30	0
Rubus spp.	23	40	62	83	60	55	30	25	50	60	77	60	77	47	15	48	48	93	75	83	60	27	48	42	87	75	62	35
Rhus copallina	0	2	7	12	7	3	0	2	7	17	12	15	12	7	2	12	28	35	30	17	7	0	5	2	17	10	10	10
Baccharis halimifolia	0	0	7	18	7	3	2	0	2	5	20	17	17	0	0	3	3	27	27	8	5	0	0	3	35	20	15	2
Berchemia scandens	13	18	17	18	20	20	18	5	13	2	5	7	12	10	8	8	2	7	15	18	12	10	5	7	7	12	17	17
Smilax spp.	25	35	30	27	12	20	18	23	22	22	27	20	22	17	30	38	45	48	30	28	18	22	15	25	22	22	27	15
Gelsemium sempervirens	65	55	62	77	75	65	42	65	45	42	70	62	72	67	72	43	32	72	63	77	65	77	72	30	47	50	72	65
Chasmanthium spp.	58	23	52	67	22	35	13	45	27	17	62	40	39	20	43	13	18	37	25	48	17	55	33	5	32	15	55	25
Panicum spp.	17	53	68	62	38	27	5	3	62	100	85	52	57	32	5	100	100	100	43	62	13	15	50	100	85	50	77	37
Andropongon virginicus	3	8	0	12	0	0	0	2	0	2	25	5	0	0	0	2	8	48	22	0	0	0	0	0	20	10	0	0
Eupatorium spp.	0	38	25	15	10	12	5	0	22	22	57	12	12	17	0	48	65	100	42	22	8	0	12	67	100	72	27	20
Lactuca canadensis	0	13	5	3	0	0	0	0	12	60	5	0	0	0	0	18	52	0	0	0	0	0	2	42	2	0	0	0
Polypremum procumbens	0	5	17	3	0	0	0	0	3	42	22	5	0	0	0	5	37	30	7	2	0	0	5	35	17	7	5	0
Conyza canadensis	0	10	7	0	0	0	0	0	0	7	0	0	0	0	0	15	38	8	0	0	0	0	2	37	7	0	0	0

hasmanthium increased. Boneset decreased and anada lettuce, which had a high NCP 1 year after ite preparation, had almost disappeared by the third rowing season. Broomsedge (*Andropogon virginicus*) ached its peak frequency on the treated plots.

Woody NCP peaked in 1976 on all but the controls, here it had peaked 1 year after clearcutting. Shrubs covered most quickly from site treatments and pro- uced the greatest NCP of all woody plant groups on l treatments. The frequency of sea-myrtle (*Baccha- is halimifolia*), absent from the uncut forest and low frequency 1 year after cutting and site preparation, aked in 1976, as did blackberry, American beauty- rry, and shining sumac (table 2). The frequency of . Peter's-wort began to decrease.

ifth Year After Site Preparation

By July 1978, the number and RFR of herbaceous ecies on all treatments other than KG fell steeply om previously recorded highs in the third year igs. 1 and 3). On KG bladed plots, species numbers eclined gradually with the slowly closing canopy of anted pines and residual hardwoods.

Frequency of panicum decreased on all treatments. roomsedge, which was nearly absent in the uncut rest, remained at high frequency on the mechani- lly treated plots, as did boneset. Canada lettuce and orse-weed disappeared completely, and polypremum sappeared from the control plots and occurred with uch lower frequency on the other treatments.

The number of woody species on all treatments anged little from 1976 levels. Generally, the RFR of oody plants increased. The RFR of shrubs on all eatments approached or exceeded precut levels. On e mechanical treatments, RFR of vines, oaks, and her trees was still below precut levels. Increases in e frequency of most trees, shrubs, and vines that ere common before disturbance indicated recovery om site treatments. Species that were either absent om the uncut forest or occurred with low frequen- es, for example, blackberry, shining sumac, sea- yrtle, and St. Peter's-wort, decreased in frequency. he decrease was most noticeable on the control plots nd to a lesser degree on the mechanical treatments.

The NCP of herbaceous plants dropped drastically om its 1976 level on all treatments. On control plots CP approached that measured in the uncut forest. urn and chop treatments were intermediate be- veen KG blade and control. KG bladed plots had the ighest NCP because the tree canopy was still open ough to permit herbaceous plant growth.

Woody NCP dropped from its 1976 high, as trees nd vines grew above the 1.5-m high measurement one for the herb-shrub stratum. Shrubs produced ost of the woody NCP.

Eighth Year After Site Preparation

The number of herbaceous species on all treatments continued to decrease from July 1978 to July 1981. Except for grasses on KG blade and other forbs on chop plots, RFR of other herbaceous plant groups also decreased (fig. 3). The number of woody species showed some increase, and with the exception of oaks on the control and chop plots, their RFR increased to precutting levels (fig. 3).

Herbaceous NCP on control plots decreased below the level measured in the uncut forest, and NCP on burn and chop plots was about equal to uncut conditions. It remained higher on the KG bladed plots. Panic grasses, chasmanthium, and boneset still occurred on KG bladed plots with greater frequency than on burn or control, but broomsedge had disappeared from all treatments (table 2).

Cushwa and others (1970) and Komarek (1974) reported that fire increased the number of legumes. In our study, legumes occurred with low RFR on all treatments and in all sampling years. They exceeded 1.0 percent RFR for more than 1 year only on the mechanical treatments. The NCP of legumes in the uncut forest ranged from 0.6 to 1.0 kg/ha. NCP peaked with 3 kg/ha on control, 7 kg/ha on burn, 16 kg/ha on chop, and 10 kg/ha on KG bladed plots; but only on the KG bladed plots did it reach 1.0 percent of the total herbaceous NCP. By 1981, NCP of legumes decreased on all treatments and ranged from 0.03 to 1.0 kg/ha, or somewhat less than in the uncut forest.

Woody NCP decreased too, but had not yet fallen to the low levels of the uncut forest. Shrubs comprised most of the NCP. The frequency of most of the common shrubs and vines increased, except for sea-myrtle, which decreased on the treated areas and occurred with low frequency on control plots (table 2).

Tenth Year After Site Preparation

By late June 1983, the number of herbaceous species fell to precutting levels. Herbaceous RFR decreased to or below precutting levels. The number of woody species were at precutting levels, but their RFR increased for most plant groups, except oaks, which showed a slight decrease (fig. 3). Oak RFR declined because most oaks had grown beyond the 1.5-m height zone and their branches no longer extended into the measured quadrat.

Polypremum had disappeared completely. Panicum grasses occurred in the uncut forest with much lower frequencies than chasmanthium. Whereas panicums had far exceeded the latter after site treatments were applied, now, 10 years later, panicums had decreased on all treatments to about the level of chasmanthium. Panicums decreased more on the dense control than on the treated plots. Chasmanthium's frequency, which decreased after timber harvesting and reached peak levels 3 to 8 years after site preparations, decreased again in 1983. Fluctuations in chasmanthium's frequencies may be explained by climatic variations (table 2).

The NCP of herbs decreased to or below precutting levels, probably because less sunlight reached the herb-shrub stratum in the dense young pine hardwood forest than in the uncut forest. The NCP of woody plants decreased to or below precutting levels, except on KG bladed plots where the stand was more open. Thus, NCP of both herbs and woody plants was greater on KG bladed plots.

CONCLUSION

The uncut forest had a dense timber overstory, and consequently few (32) herbaceous plant species were present. There were 64 woody species. Total NCP of the herb-shrub stratum averaged 359 kg/ha, 86 percent of which was from woody plants.

One growing season after the merchantable timber was cut and removed, the number of herbaceous species doubled. Most of this increase was in grasses, composites, and other forbs. The number of woody species decreased only on the plots that were chopped in the fall of 1972. Both herbaceous and woody NCP increased.

One growing season after site preparation treatments in the fall of 1973, the number and NCP of herbaceous species further increased. Burning and, in particular, the mechanical site treatments, reduced the number, RFR, and NCP of woody species. Frequency of some herbs and woody plants, absent from the uncut forest, peaked one growing season after site preparation.

Three growing seasons after site preparation (1976), the number of herb species peaked, though the RFR of some herbaceous plant groups began to decline. The number of woody plants nearly recovered to precutting levels, and their RFR increased. Frequency of sea-myrtle and broomsedge peaked on all plots. Boneset peaked on the mechanical treatments. Canada lettuce and horse-weed all but disappeared. Total woody NCP peaked on the prepared areas, while herbaceous NCP began to decline.

From the fifth through the tenth growing season after site preparation, the number, RFR, and NCP of herbaceous species continued to decrease as the canopy of planted pines and residual hardwoods gradually closed. By July of the tenth year, the number, RFR, and NCP of herbaceous species approached or fell below the low levels recorded in the uncut forest. At the same time the woody plants regained precut species numbers, and their NCP dropped below that found in the uncut forest on all but the KG bladed plots. Except for KG bladed plots, most woody plant groups exceeded their RFR in the uncut forest.

During the 12-year regeneration cycle—from saw timber stand through clearcutting, site preparation, pine planting, and to the established pine plantations—average NCP in the herb-shrub stratum increased tenfold, from 359 kg/ha to 3,462 kg/ha at the peak NCP of each site treatment, and then dropped to nearly its initial low level (383 kg/ha) in 1983. The number of herbaceous species more than doubled at the peak, but fell to the low precutting levels as the crown canopy closed. The number of woody species dropped temporarily after site preparation, but regained precutting levels after 10 growing seasons. Some herbaceous and woody species that were absent from the uncut forest peaked with high frequency after site preparation, then disappeared, or nearly so, two to five growing seasons later.

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During the 12-year regeneration cycle—from sawtimber stand through clearcutting, site preparation, pine planting, and to the established pine plantations—average net community production in the herb-shrub stratum increased tenfold, from 369 to 3,462 kg/ha at the peak of each site treatment, and nearly dropped to its initial low level after 10 years.

Keywords: Herb/shrub relative frequency, undergrowth, forest management, plant succession.

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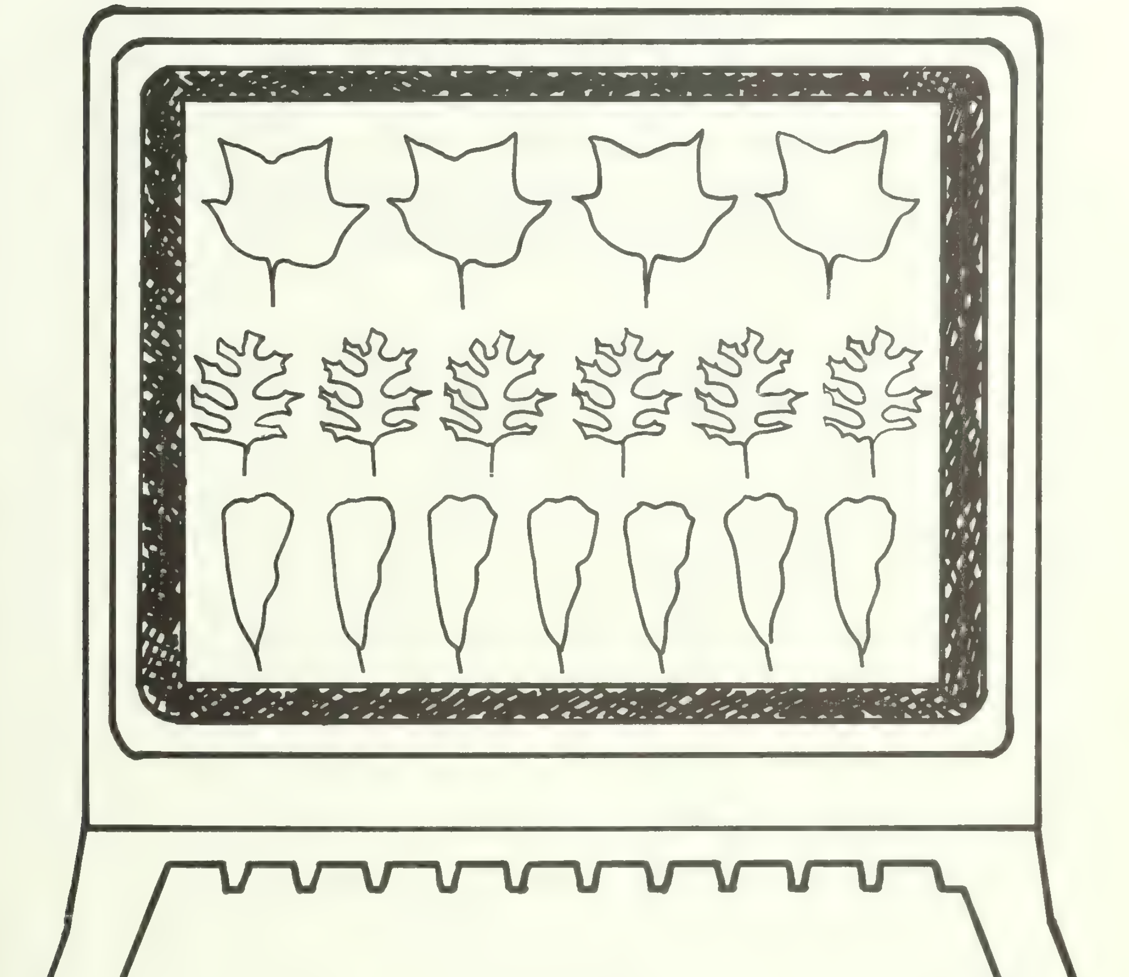
SITEQUAL—A User's Guide

Computerized Site Evaluation for 14 Southern Hardwood Species

Constance A. Harrington and Bettina M. Casson



SUMMARY

An interactive computer program, SITEQUAL, has been developed from the widely-used Baker and Broadfoot field guides, which evaluate site quality for 14 southern hardwood tree species. The SITEQUAL program calculates site index for all species simultaneously and provides a breakdown of site index into the component contributions by each of the four major soil factors defined by Baker and Broadfoot. When the necessary soil-site information is available, SITEQUAL can be used to rapidly evaluate a series of site conditions for all species or to determine the relative sensitivity of these species to specific conditions including past or proposed land use practices.

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Computerized Site Evaluation for 14 Southern Hardwood Species

Constance A. Harrington and Bettina M. Casson

INTRODUCTION

n the late 1970's, James B. Baker and Walter M. oadfoot of the Southern Forest Experiment Station blished field guides for evaluating site quality for commercially important hardwood species in the uthern United States (Baker and Broadfoot 1977, 79). These field guides enable the user to evaluate four major soil factors of physical condition, mois- e availability, nutrient availability, and aeration, then to calculate site index for any of the follow- 14 hardwood tree species: cottonwood (*Populus toides*), green ash (*Fraxinus pennsylvanica*), pecan *rya illinoensis*), sycamore (*Platanus occidentalis*), etgum (*Liquidambar styraciflua*), yellow poplar *iodendron tulipifera*), hackberry (*Celtis occiden- s*), sugarberry (*C. laevigata*), cherrybark oak *ercus falcata* var. *pagodifolia*), Nuttall oak (*Q. tallii*), Shumard oak (*Q. shumardii*), water oak (*Q. ra*), willow oak (*Q. phellos*), and swamp chestnut (*Q. michauxii*). The field guides require the user nswer a series of questions which quantify the soil site conditions of the area being evaluated. Infor- ion is required on: soil depth, texture, structure, compaction; presence of a pan; past use and ent vegetative cover; topographic position includ- depth to water table, swampiness, length of flood- and microrelief; soil age and geologic source of parent material; pH, organic matter; and soil r. The questions are presented in a modified iple-choice format with each species evaluated in rate site evaluation tables.

his report describes the use of an interactive com- r program, SITEQUAL, which was developed the Baker-Broadfoot field guides. SITEQUAL icts site index for all 14 hardwood species at the time. The program requires the same user-supplied information as the published site evaluation tables and there are no differences in the site index[1] predicted for any species between the program and the Baker-Broadfoot field guides. SITEQUAL does differ from the Baker-Broadfoot field guides in the order and format in which questions are asked; these differences in organization allow all species to be evaluated simultaneously and reduce the overlap between questions. Several versions of the program are available for different types and models of computers.

The major advantages of using the SITEQUAL program are completeness and speed. In the past, users of the Baker-Broadfoot field guides would commonly evaluate only 3 or 4 hardwood species for a site rather than all of the 14 possible species. This partial evaluation ran the risk of overlooking species that might be more productive than the species evaluated. In addition, the speed at which different sets of site conditions can be evaluated makes the SITEQUAL program more efficient to use than the field guides, especially when a user has the necessary soil-site data already "in hand" for several areas.

Cautions

The SITEQUAL program only evaluates the site conditions used as input data, and all 14 hardwood species will be evaluated for a site, regardless of whether or not all species naturally occur on a particular soil. In addition, the broad geographic area of applicability for the program is the same as that specified in the field guides, i.e., "the southern hard-

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[1] In the Baker-Broadfoot field guides the phrase "site quality rateing" was used to refer to potential or calculated site index. In this report, the more commonly used phrase, site index, is used in place of site quality rating.

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wood region except in those mountainous areas where aspect is important" (Baker and Broadfoot 1979, p 2). Neither the program nor the field guides should be used without modification outside this region unless local testing indicates their applicability.

It is highly recommended that potential users of SITEQUAL read the Baker-Broadfoot field guides before using the program. The field guides illustrate how the site index values are calculated and contain useful background information on assessing soil and site properties.

PROGRAM SITEQUAL

Organization

The SITEQUAL program consists of 12 major program segments with each segment containing the calculations for 1 or 2 species. Hackberry and sugarberry are evaluated in one program segment, water oak and willow oak are evaluated together in another program segment, and the other 10 species are evaluated individually. The first program segment is for cottonwood; in addition to calculating site index for cottonwood, this segment also contains all of the questions, and accepts the answers for all of the other species. The answers given in the first program segment are checked to see if they are within acceptable ranges for that question. If an answer is not acceptable the question is repeated. If answers given in the first program segment are acceptable, they are automatically passed to the next 11 program segments for calculation of the site index values for the other species. The program logic is flowcharted in Appendix C.

Site index (SI) is calculated by summing the value obtained in each of four major soil factors: (1) Physica condition; (2) Moisture availability during the growing season; (3) Nutrient availability; and (4) Aeration SITEQUAL calculates a factor value by summing th values assigned to the individual soil-site propertie The percentage of the maximum allowable value i also determined for each factor and specie combination. Several individual soil-site condition were considered by Baker and Broadfoot to indicat the site was unsuitable for a species. Those site conditions, given in table 1, result in the species bein assigned an unsuitable rating in the output with footnote indicating the reason for the rating (see examples in Appendix A). The computed SI value is als compared to the minimum acceptable value established by Baker and Broadfoot for each specie (table 1). A footnote in the output table indicates if th calculated value is below the minimum acceptabl value.

Questions and Answers

The SITEQUAL program requires information o various soil and site characteristics (table 2). Mos answers can be selected from a multiple choice format. The user needs to press only one number key an then the <RETURN> or <ENTER> key. A site identification in the form of a number or name is require any combination of letters, numbers, spaces, or special characters can be used, up to a maximum of 1 characters or spaces. Values for pH can be input a either whole numbers (e.g. 5) or with decimal fractions (e.g. 4.5). All other questions require a singl digit response. Out of range answers result in th question being asked again.

Table 1.—*Summary of minimum site index values and unsuitable soil-site conditions which result in comment footnotes in the program output*

Tree species	Minimum SI[1] considered acceptable for management	Condition resulting in unsuitable ratings and footnoted by program			
		Water table <1 foot	Water-logging	pH>7.5	Flooding continuous
	--- *Feet* ---				
Cottonwood	80	x	x		x
Green Ash	65		x		
Hackberry, Sugarberry	55	x	x		x
Cherrybark Oak	70	x	x	x	x
Nuttall Oak	75	x	x	x	x
Shumard Oak	70	x	x	x	x
Swamp Chestnut Oak	65	x	x	x	x
Water Oak, Willow Oak	70	x	x	x	x
Pecan	70	x	x		x
Sweetgum	75	x	x		x
Sycamore	70	x	x		x
Yellow Poplar	70	x	x		x

[1] SI is site index at age 30 for cottonwood, age 50 for other species.

able 2.—*Listing of SITEQUAL questions and possible answers. Questions preceded by a * are only asked if the user's response to a previous question triggers the program to ask for additional information.*

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his program predicts site index for 14 southern hardwood species. It requires the user to answer questions on soil properties and site aracteristics for each area that is evaluated. The questions are answered by pressing the appropriate key or keys (most answers are a 1-digit mber) followed by pressing the <RETURN> key.

o you wish to run this program?
) Yes
) No

put Site number or name

put presence of artificial or inherent pan from the following list:
(Without pan
(Plowpan
(Inherent pan

*put depth of soil that can be readily occupied by roots from the following list:
(Deep soil; >4 feet
(Medium soil; 2–4 feet
(Shallow soil; <2 feet

es the soil contain any stratified horizons within the effective rooting zone?
(Yes, major horizons are stratified
(No, major horizons are not stratified

ut the structure in rooting zone from the following list:
(Granular
(2 Massive (if silty, loamy, or mucky)
(3 Massive (if clayey)
(4 Single grained (if sandy)
(5 Prismatic
(6 Platy
(7 Blocky

*put the soil texture in rooting zone from the following list:
(1 Fine-textured; clayey
(2 Medium-textured; silty or loamy
(3 Coarse-textured; sandy

C ssify compaction in the surface foot from the following list:
(1 No compaction; loose, porous, friable; (bulk density <1.4 g/cc)
(2 Moderately compacted; firm, moderately tight; (bulk density 1.4–1.7 g/cc)
(3 Strongly compacted; tight; (bulk density >1.7 g/cc)

In ut present cover from the following list:
(1 Forest cover (includes sites recently clearcut)
(2 Open with grass cover
(3 Open and bare

*I w many years has this site been cultivated or pastured?
(1) (i.e. never cleared for cultivation or pasture)
(2 1–4 years
(3 5–9 years
(4 10–19 years
(5 20 years or more

*D past farming cultural practices include annual fertilization?
(1 Yes
(2 No

In t average depth to water table during the growing season from the following list:
(1) <1 foot
(2) –2 feet
(3) –6 feet
(4) –10 feet
(5) >10 feet

Table 2.—*Listing of SITEQUAL questions and possible answers. Questions preceded by a * are only asked if the user's response to a previ question triggers the program to ask for additional information.—Continued*

Input the topographic position from the following list:
(1) Floodplain or stream bottom
(2) Stream terraces or lower slopes
(3) Upland

Input the microsite from the following list:
(1) Concave; depression, pocket, trough
(2) Level; flat
(3) Convex; ridge, mound

Input flooding times from the following list:
(1) Winter through spring
(2) Winter only
(3) None
(4) Continuous

Input the geologic source from the following list:
(1) Mississippi River, Loess, Blackland
(2) Mixed Coastal Plain and other
(3) Coastal Plain

Input the organic matter in A-horizon from the following list:
(1) Organic matter >2%
(2) Organic matter ≥1% or Organic matter ≤2%
(3) Organic matter <1%

Input depth of topsoil (A-horizon) from the following list:
(1) >6 inches or no profile development
(2) 3–6 inches
(3) <3 inches

Input soil age from the following list:
(1) Young; no profile development (Entisols)
(2) Medium; moderate profile development (Inceptisols)
(3) Old; well-developed profile, leached (Alfisols, Ultisols)

Input pH in rooting zone. EX. 5.5

Input swampiness from the following list:
(1) Wet in winter only
(2) Wet January-July
(3) Waterlogged all year

Input mottling from the following list:
(1) None to 18 inch depth
(2) None to 8 inch depth
(3) Mottled to surface or gray mineral soil

Input soil color in rooting zone from the following list:
(1) Black, brown, red
(2) Yellow, brownish-gray
(3) Gray

Do you want a listing of your input values.
(1) Yes, please provide a listing
(2) No, input listing is not necessary

Do you want to do another set of site evaluations?
(1) Yes
(2) No

tions

The program provides the user with three choices or tions. When SITEQUAL begins, it presents an in- ductory paragraph and asks the user whether he or e wishes to run the program (table 2). If the user esses 1 (meaning Yes, followed by pressing ETURN>), the program continues by asking the er to “Input site number or name”. If the user esses 2 (meaning No, followed by pressing ETURN>), the program goes to the END state- nt and stops. Thus, the first option provides the r a chance to exit the program gracefully (i.e. with- “crashing”).

he other two choices offered the user occur at the l of the program-user dialog. The user is first ed, “Do you want a listing of your input values?” If question is answered affirmatively (by pressing 1 l then <RETURN>), a list of the input values for h soil-site property will be printed above the basic mmary table (see table 3). The input values listed respond to the categories selected by the user. For mple the “1” printed to the right of “Presence of ” in table 3 corresponds to the category “(1) Without pan” in the listing of the SITEQUAL questions (table 2). If the question on input values is answered negatively, only the basic summary table is provided. Immediately after answering this question, the output will begin printing (see discussion under “Versions of SITEQUAL” for systems without a printer). Following the printing of the output, the program will ask, “Do you want to do another set of site evaluations?” If the answer is Yes (i.e., 1 was pressed), the program will loop back to the beginning and restart. If No is selected (i.e., 2 is pressed), the program goes to the END statement and stops.

EXAMPLES AND USES

The output available from a run of SITEQUAL is illustrated in table 3. It is composed of a title, site identification, optional listing of input values, and summary table. For all 14 hardwood species the program calculates the number of points assigned in each of the four soil factors and the total site index. In addition, the calculated value for each factor is di-

Table 3.—*Example of output obtained using SITEQUAL program and selecting the option to print the input values. SI is site index in feet at 30 years for cottonwood and 50 years for the other species*

SITEQUAL—Site Evaluation for 14 southern hardwoods.

Site ID Example 1

Input values for each soil site property.

Presense of pan	1	Soil depth	1
Stratification	1		
Soil structure	1	Soil texture	2
Compaction	1	Present cover	1
Water table depth	4	Topographic position	1
Microsite	2	Flooding times	1
Geologic source	1	Organic matter	1
Topsoil depth	1	Soil age	1
pH	7	Swampiness	1
Mottling	1	Soil color	1

Species	Number of points and % of total possible by factor				Total SI
	Physical condition	Moisture avail.	Nutrient avail.	Aeration	
Cottonwood	46(100%)	41(89%)	26(100%)	12(100%)	125
Green Ash	21(100%)	40(85%)	26(100%)	10(100%)	97
Hackberry, Sugarberry	25(100%)	22(88%)	25(100%)	25(100%)	97
Cherrybark Oak	31(100%)	34(89%)	23(92%)	31(100%)	119
Nuttall Oak	24(100%)	31(74%)	28(93%)	24(100%)	107
Shumard Oak	31(100%)	28(88%)	27(93%)	30(100%)	116
Swamp Chestnut Oak	28(100%)	29(94%)	22(92%)	26(100%)	105
Water Oak, Willow Oak	29(100%)	30(88%)	21(91%)	29(100%)	109
Pecan	27(100%)	27(90%)	30(100%)	28(100%)	112
Sweetgum	30(100%)	32(89%)	24(100%)	30(100%)	116
Sycamore	32(100%)	16(80%)	39(100%)	39(100%)	126
Yellow Poplar	40(100%)	27(90%)	25(100%)	30(100%)	122

vided by the maximum number possible and the resulting percentage is printed. This calculation enables the user to readily identify which of the four major soil factors is at the least optimum level. In the example given in table 3, two of the soil factors evaluated for Nuttall oak have similar values—Moisture Availability (31) and Nutrient Availability (28). In the model developed by Baker and Broadfoot, however, moisture availability during the growing season was considered to be more important than nutrient availability in determining site quality for Nuttall oak; thus, the percentage of total points possible differs between the two soil factors (74 percent versus 93 percent). The soil factor achieving the lowest *percentage*—moisture availability in the above example—was considered by Baker and Broadfoot as the factor that was most limiting to tree growth on that site.

Another possible use of the SITEQUAL program is to evaluate the relative sensitivity of these hardwood tree species to past land use practices (e.g., agricultural cropping) or proposed future practices (e.g., construction of a drainage system). For example, the values in table 4 were determined by using the same basic soil characteristics as in table 3, but in the ond case the site had been cropped for 30 years rat than having been under tree cover. For this scen it was assumed that 30 years of cropping had cau development of a plow pan and moderate compact in the surface foot of soil but that little topsoil been lost due to erosion. Predicted site index lower for all species (after cropping), but the mag tude of the reduction varied by species. Cottonw was the species most sensitive to the site chan associated with cropping, losing a total of 36 fee potential site index (125 minus 89). Pecan was least sensitive, losing 23 feet of site index.

VERSIONS OF SITEQUAL

Similarities and Differences

SITEQUAL was written in the BASIC compu language; unfortunately since a standardized vers of BASIC does not exist, several versions of the p gram needed to be created so the program could be r on different types and models of computers (table

Table 4.—*Example of SITEQUAL output. Soil and site conditions in this example are the same as in table 3 except for example 2 it was assumed the site had been cultivated for 30 years. As a result of cultivation, a plow pan and moderate compaction developed and organic matter content was decreased.*

SITEQUAL—Site Evaluation for 14 southern hardwoods.

Site ID Example 2

Input values for each soil site property.

Presense of pan	2		
Stratification	1		
Soil structure	1	Soil texture	2
Compaction	2	Present cover	3
Past use	5	Fertilization	2
Water table depth	4	Topographic position	1
Microsite	2	Flooding times	1
Geologic source	1	Organic matter	3
Topsoil depth	1	Soil age	1
pH	7	Swampiness	1
Mottling	1	Soil color	1

Species	Number of points and % of total possible by factor				Total SI
	Physical condition	Moisture avail.	Nutrient avail.	Aeration	
Cottonwood	31(67%)	35(76%)	11(42%)	12(100%)	89
Green Ash	13(62%)	34(72%)	14(54%)	10(100%)	71
Hackberry, Sugarberry	16(64%)	17(68%)	15(60%)	25(100%)	73
Cherrybark Oak	20(65%)	29(76%)	14(56%)	31(100%)	94
Nuttall Oak	14(58%)	24(57%)	16(53%)	24(100%)	78
Shumard Oak	20(65%)	23(72%)	18(62%)	30(100%)	91
Swamp Chestnut Oak	17(61%)	22(71%)	14(58%)	26(100%)	79
Water Oak, Willow Oak	19(66%)	25(74%)	13(57%)	29(100%)	86
Pecan	17(63%)	22(73%)	21(70%)	28(100%)	88
Sweetgum	20(67%)	27(75%)	14(58%)	30(100%)	91
Sycamore	20(63%)	11(55%)	25(64%)	39(100%)	95
Yellow Poplar	26(65%)	21(70%)	16(64%)	30(100%)	93

Table 5.—*Summary of SITEQUAL versions*

Language of version	Tested on these machines	Special comments
HP BASIC	Hewlett Packard 9845	When doing repeated, sets of site evaluations, user can press <CONT> key for values that do not change between sites.
AppleSoft™ BASIC	Apple IIc, IIe	Both 40-and 80-column versions are available.
MicroSoft™ BASIC	IBM-PC, North Star Advantage, Cromemco, Panasonic Sr. Partner, Compaq D G Dasher One	North Star version reloads program for subsequent runs, other MicroSoft™ versions go to question asking for site ID.
BASIC-11	DEC-PDP-11/23	Program creates output file; user must send output file to printer.

All versions of the program give identical answers. We have only run the program on the computer models listed in the table; however, virtually any machine that runs MicroSoft™ BASIC should run the MicroSoft™ BASIC interpreted version of SITEQUAL without changes. Although the language version of the program may be the same for many machines, the user must make sure he or she uses the right type of diskette, data cartridge, or tape and that it has been correctly formatted for his or her system.

The AppleSoft™ BASIC and BASIC-11 versions of the program differ from the other two major versions n that they do not utilize any IF/THEN/ELSE statements, and variable names are limited to two characters (Appendix B). Other machines with similar requirements for their type of BASIC may be able to run one of these program versions with little or no modification.

All versions of SITEQUAL except the BASIC-11 version automatically route the program output to the printer port. If a "printer version" of the program is run on a machine which is not connected to a printer, he output phase of the program will result in an error message or will cause the machine to "freeze". If the user wishes to run the program but does not have access to a printer, all LPRINT statements in the program (for the printer) must be changed to PRINT statements (for the screen).

With the Hewlett Packard Interpreter all soil-site variable values and all question values are retained n memory. Thus, when evaluating more than one ite, the values from the first evaluation can be input for the second evaluation by pressing <CONT>. This allows the user to change the value of any variable that is different, but eliminates the need to re-input values that are the same as were used in the evaluation of the previous site. On most other systems each time a site is evaluated the program is loaded back in memory, a process which erases any soil-site variable values or question values that were used previously. The user must supply a new value for each question every time a new site is evaluated.

The AppleSoft™ version of SITEQUAL is available in both 40 column and 80 column subversions. The versions are almost identical except for formatting. However, if the 80 column version is run on a machine that does not contain an 80 column card, the program will be scrambled. After initially turning on the 80 column card, it is not necessary to repeat the process, as the program does it automatically after each site evaluation table is printed.

Availability

A program listing, program documentation, or copies of the SITEQUAL program may be obtained by contacting the authors at the Southern Forest Experiment Station, Box 3516, Monticello, AR 71655, 501-367-3464. Requests by mail should include a name, address, and phone number as well as a blank diskette, data cartidge, or tape which is compatible with the version being requested. If a MicroSoft™ BASIC version is desired, please indicate whether a compiled or an interpreted program is needed. An interpreted program can be changed by the user; however, in order to actually run an interpreted program, the user must have a BASIC interpreter software program that is compatable with the user's system. Compiled programs can be run without additional software but cannot be altered.

LITERATURE CITED

Baker, J.B., Broadfoot, W.M. A practical field method of site evaluation for eight important southern hardwoods. Gen. Tech. Rep. SO-14. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1977. 31 p.

Baker, J.B., Broadfoot, W.M. A practical field method of site evaluation for commercially important southern hardwoods. Gen. Tech. Rep. SO-26. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1979. 51 p.

APPENDIX A

Examples of Special Cases

The following two examples illustrate the footnotes that appear when the site quality rating is below the minimum acceptable value established for a species (example 3) or when a specific soil-site property makes the site unsuitable for a species (example 4).

Site ID Example 3

Species	Number of points and % of total possible by factor				Total SI
	Physical condition	Moisture avail.	Nutrient avail.	Aeration	
Cottonwood	11(24%)	7(15%)	26(100%)	11(92%)	55@
Green Ash	6(29%)	22(47%)	26(100%)	9(90%)	63@
Hackberry, Sugarberry	11(44%)	11(44%)	25(100%)	23(92%)	70
Cherrybark Oak	15(48%)	14(37%)	23(92%)	27(87%)	79
Nuttall Oak	9(38%)	19(45%)	28(93%)	22(92%)	78
Shumard Oak	15(48%)	15(47%)	27(93%)	26(87%)	83
Swamp Chestnut Oak	12(43%)	14(45%)	22(92%)	24(92%)	72
Water Oak, Willow Oak	14(48%)	13(38%)	21(91%)	27(93%)	75
Pecan	14(52%)	15(50%)	30(100%)	25(89%)	84
Sweetgum	15(50%)	12(33%)	24(100%)	26(87%)	77
Sycamore	9(28%)	1(5%)	39(100%)	36(92%)	85
Yellow Poplar	13(33%)	16(53%)	25(100%)	24(80%)	78

@Total SI is below minimum site index considered reasonable for planting or managing this species unless soil conditions can be improved.

Site ID Example 4

Species	Number of points and % of total possible by factor				Total SI
	Physical condition	Moisture avail.	Nutrient avail.	Aeration	
Cottonwood	22(48%)	40(87%)	17(65%)	11(92%)	90
Green Ash	14(67%)	42(89%)	18(69%)	9(90%)	83
Hackberry, Sugarberry	15(60%)	21(84%)	21(84%)	23(92%)	80
Cherrybark Oak	....	....	.......*	....	Unsuitable
Nuttall Oak	....	....	.......*	....	Unsuitable
Shumard Oak	....	....	.......*	....	Unsuitable
Swamp Chestnut Oak	....	....	.......*	....	Unsuitable
Water Oak, Willow Oak	....	....	.......*	....	Unsuitable
Pecan	16(59%)	26(87%)	26(87%)	25(89%)	93
Sweetgum	21(70%)	31(86%)	19(79%)	30(100%)	101
Sycamore	19(59%)	15(75%)	30(77%)	36(92%)	100
Yellow Poplar	20(50%)	25(83%)	18(72%)	24(80%)	87

*Site is classified unsuitable for this species because pH is above 7.5.

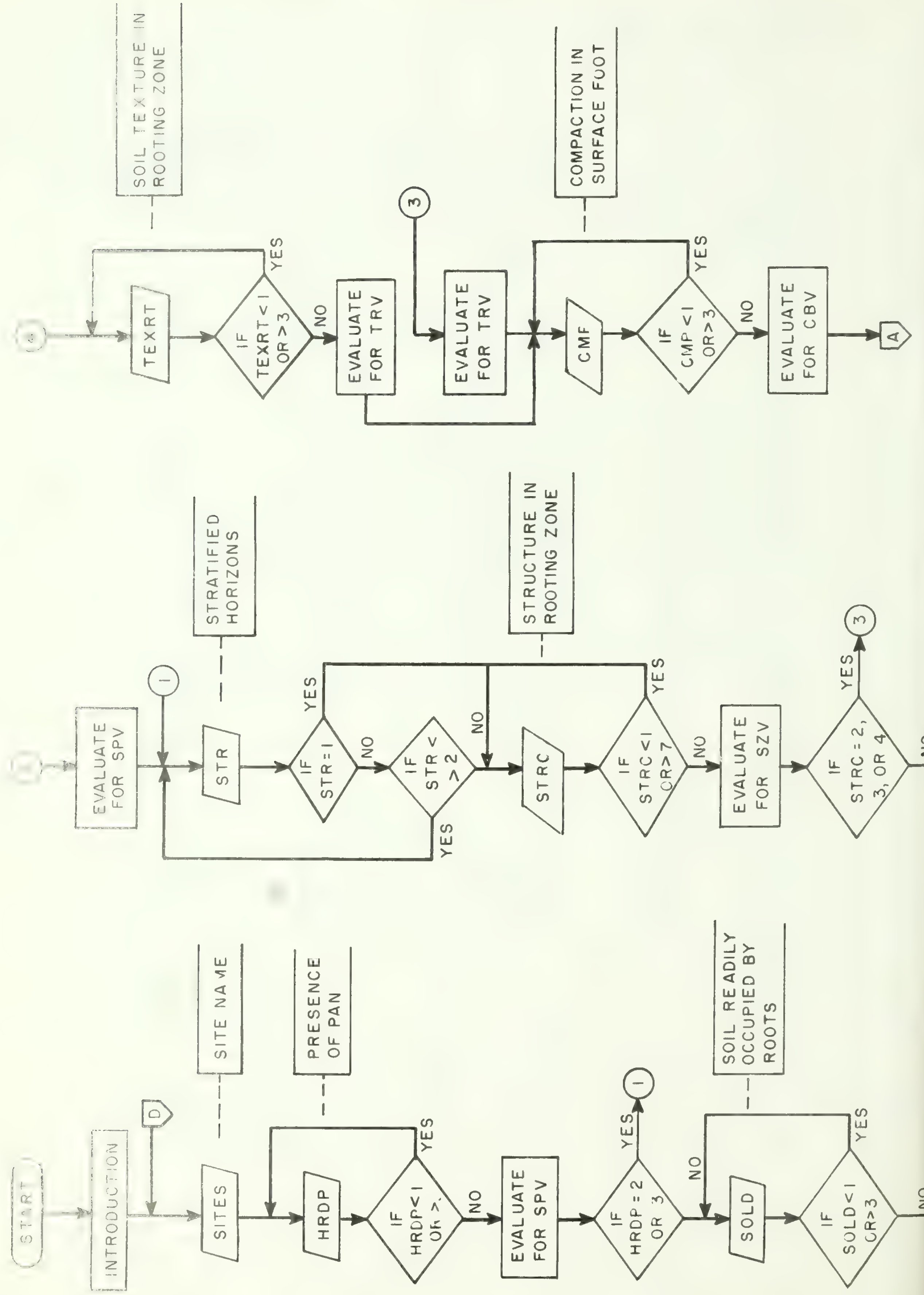
APPENDIX B

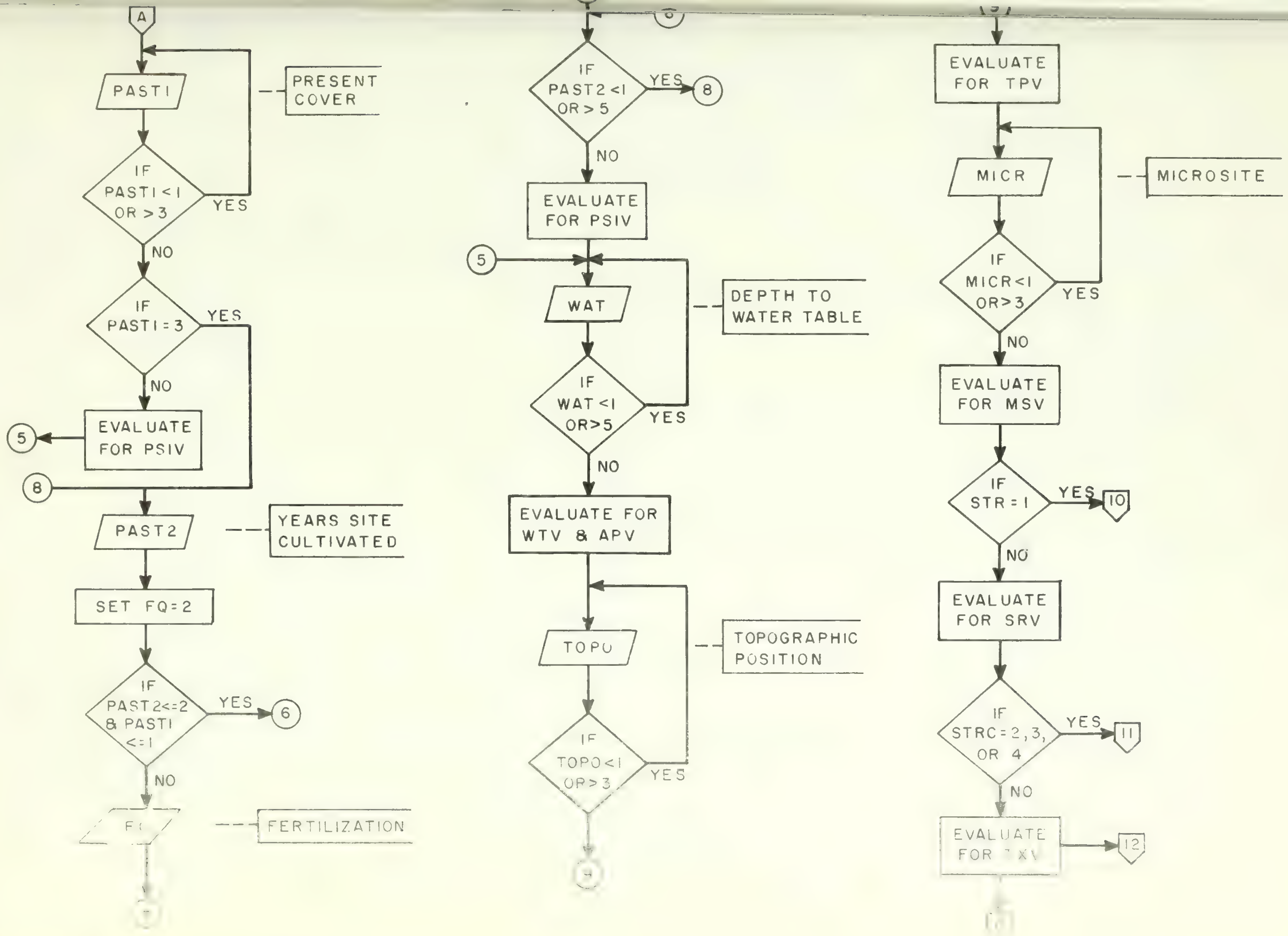
Soil-site and factor variable names by program version

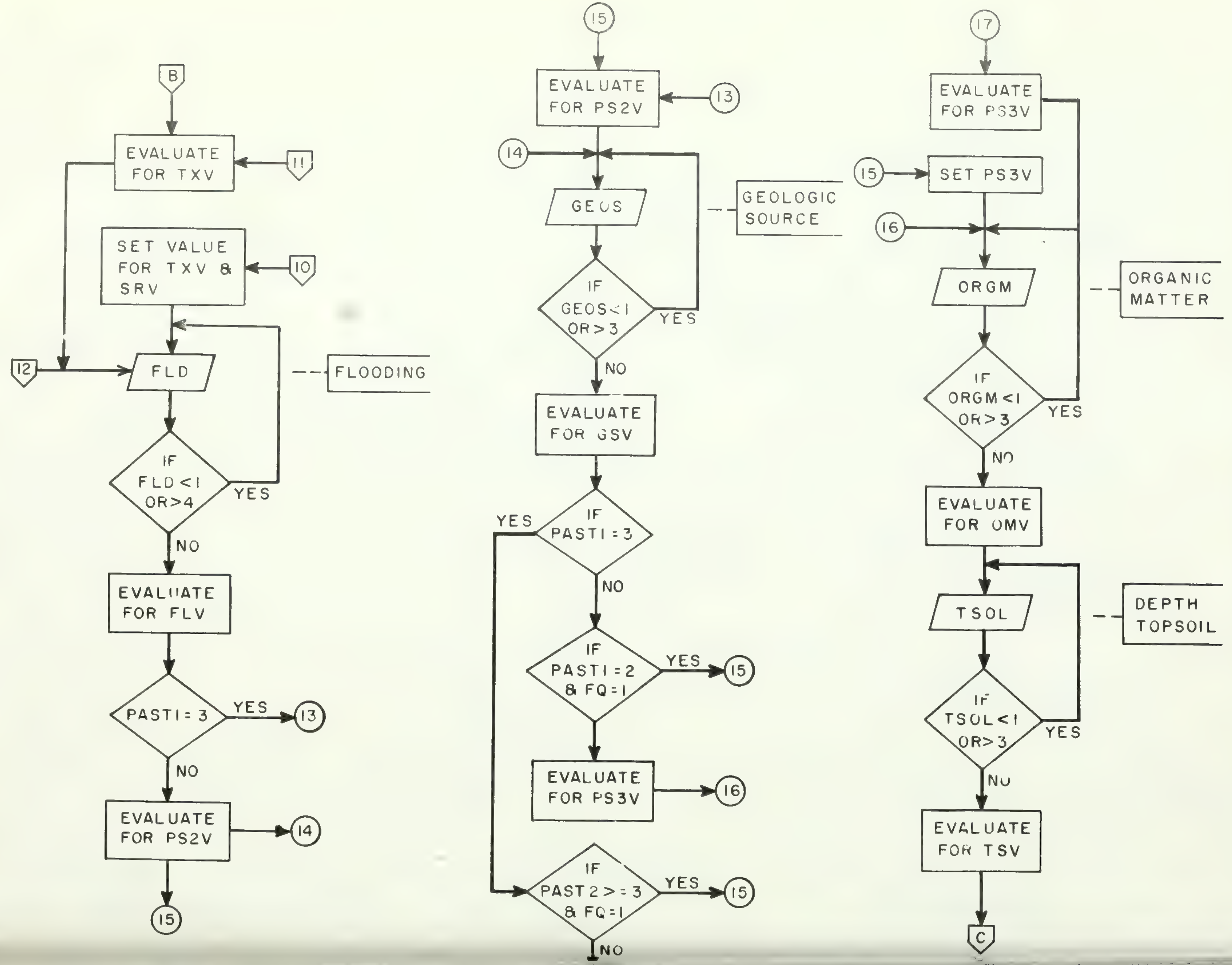
Soil-site variables		Conditions being quantified	Factor variables	
MicroSoft version	All other versions		MicroSoft version	All other versions
Factor 1. Physical condition				
HRDP	H1	Hardpan	SPV	S9
SOLD	S3	Soil Depth	SPV	S9
STRC	S5	Soil Structure	SZV	Z9
TEXRT	T1	Texture (Rooting Zone)	TRV	T9
CMP	C1	Compaction	CBV	C9
PAST1	P1	Present Cover	PS1V	P9
PAST2	P2	Cultivation	PS1V	P9
Factor 2. Moisture availability during the growing season				
WAT	W1	Water Table Depth	WTV	W9
HRDP	H1	Hardpan	APV	A9
TOPO	T2	Topographic Position	TPV	T8
MICR	M1	Microsite	MSV	M9
STRC	S5	Soil Structure	SRV	R9
STR	S4	Stratification	SRV	R9
TEXRT	T1	Texture (Rooting zone)	TXV	T7
FLD	F7	Flooding	FLV	F9
PAST1	P1	Present Cover	PS2V	P8
PAST2	P2	Cultivation	PS2V	P8
Factor 3. Nutrient availability				
GEOS	G1	Geologic Source	GSV	G9
PAST1	P1	Present Cover	PS3V	P6
PAST2	P2	Cultivation	PS3V	P6
FQ	F6	Fertilization	PS3V	P6
ORGM	O1	Organic Matter	OMV	O9
TSOL	T3	Topsoil	TSV	T6
SOLA	S1	Soil Age	SAV	A8
PH	P3	pH	PHV	P7
Factor 4. Aeration				
STRC	S5	Soil Structure	SZ2V	S8
SWP	S6	Swampiness	SWV	W8
MOTT	M2	Mottling	MTV	M8
SOLC	S2	Soil Color	SCV	C8

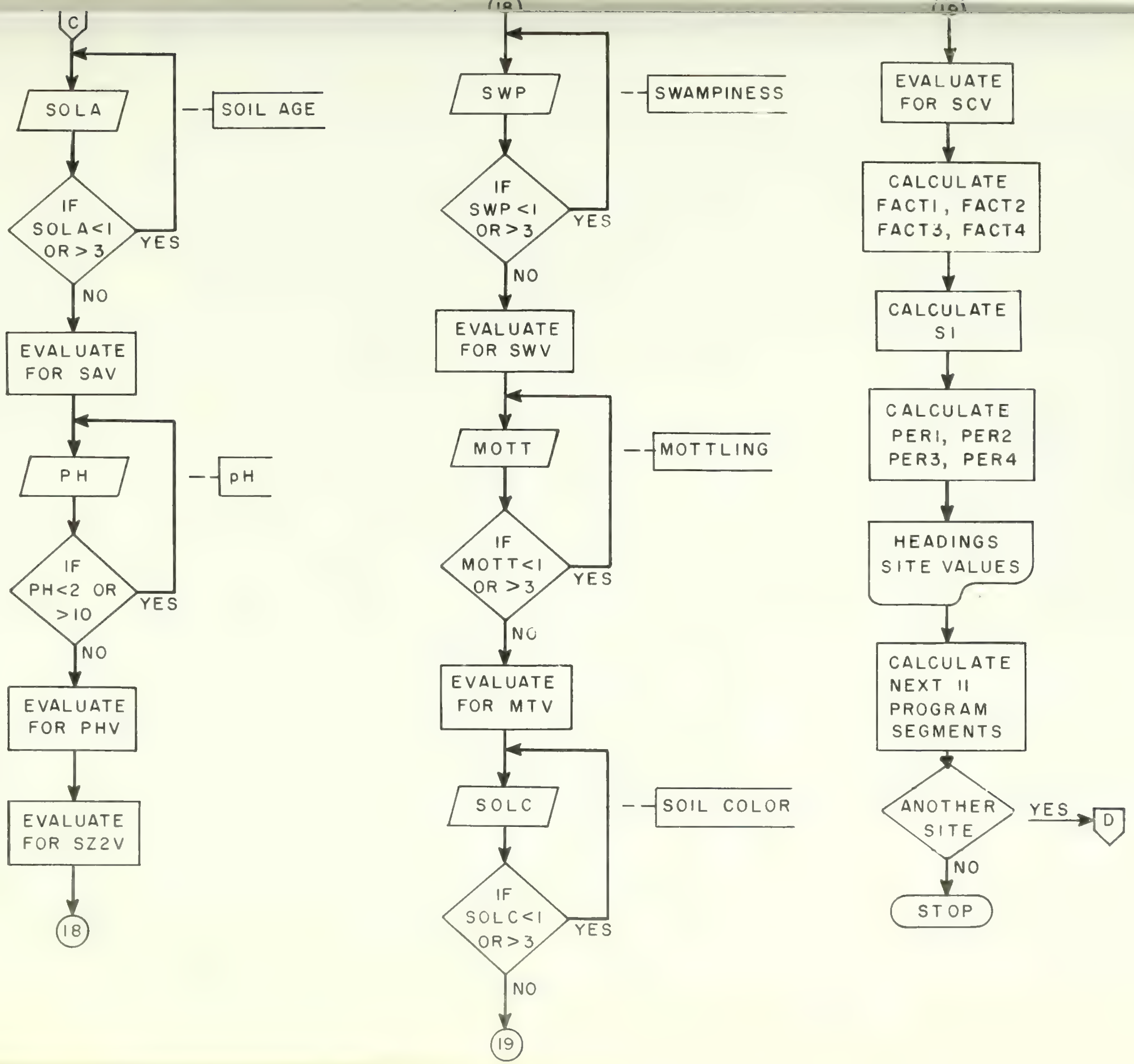
APPENDIX C

Flowchart of the SITEQUAL program




A
PASTI
PRESENT COVER
IF PASTI < I OR > 3
YES
NO
IF PASTI = 3
YES
NO
EVALUATE FOR PSIV
5
8
PAST2
YEARS SITE CULTIVATED
SET FQ=2
IF PAST2<=2 & PASTI <=I
YES
6
NO
FERTILIZATION
IF PAST2 <I OR > 5
YES
8
NO
EVALUATE FOR PSIV
5
WAT
DEPTH TO WATER TABLE
IF WAT <I OR>5
YES
NO
EVALUATE FOR WTV & APV
TOPO
TOPOGRAPHIC POSITION
IF TOPO<I OR>3
YES
EVALUATE FOR TPV
MICR
MICROSITE
IF MICR<I OR>3
YES
NO
EVALUATE FOR MSV
IF STR=I
YES
10
NO
EVALUATE FOR SRV
IF STRC=2,3, OR 4
YES
11
NO
EVALUATE
12


B
EVALUATE FOR TXV
11
SET VALUE FOR TXV & SRV
10
12
FLD
FLOODING
IF FLD<1 OR>4
YES
NO
EVALUATE FOR FLV
PAST1=3
YES
13
NO
EVALUATE FOR PS2V
14
15
15
EVALUATE FOR PS2V
13
14
GEOS
GEOLOGIC SOURCE
IF GEOS<1 OR>3
YES
NO
EVALUATE FOR GSV
IF PAST1=3
YES
NO
IF PAST1=2 & FQ=1
YES
15
EVALUATE FOR PS3V
16
IF PAST2>=3 & FQ=1
YES
15
NO
17
EVALUATE FOR PS3V
15
SET PS3V
16
ORGM
ORGANIC MATTER
IF ORGM<1 OR>3
YES
NO
EVALUATE FOR OMV
TSOL
DEPTH TOPSOIL
IF TSOL<1 OR>3
YES
NO
EVALUATE FOR TSV
C


C
SOLA
SOIL AGE
IF SOLA<I OR >3
YES
NO
EVALUATE FOR SAV
PH
pH
IF PH<2 OR >10
YES
NO
EVALUATE FOR PHV
EVALUATE FOR SZ2V
18
SWP
SWAMPINESS
IF SWP <I OR >3
YES
NO
EVALUATE FOR SWV
MOTT
MOTTLING
IF MOTT<I OR >3
YES
NO
EVALUATE FOR MTV
SOLC
SOIL COLOR
IF SOLC<I OR >3
YES
NO
19
EVALUATE FOR SCV
CALCULATE FACTI, FACT2 FACT3, FACT4
CALCULATE SI
CALCULATE PERI, PER2 PER3, PER4
HEADINGS SITE VALUES
CALCULATE NEXT II PROGRAM SEGMENTS
ANOTHER SITE
YES
D
NO
STOP

METRIC EQUIVALENTS

1 foot = 3.28 meters
1 inch = 2.54 centimeters

The use of trade or firm names in this publication is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

Harrington, Constance A., and Casson, Bettina M. SITEQUAL—A user's guide. Computerized site evaluation for 14 southern hardwood species. Gen. Tech. Rep. SO-62. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1986, 13 p.

SITEQUAL, an interactive computer program, evaluates site quality for 14 southern hardwood tree species. This report rapidly evaluates site conditions for all species or determines the relative sensitivity of these species to specific conditions, including past or proposed land use practices.

Additional keywords: Soil-site prediction, site index, site quality, computer programs/programming.

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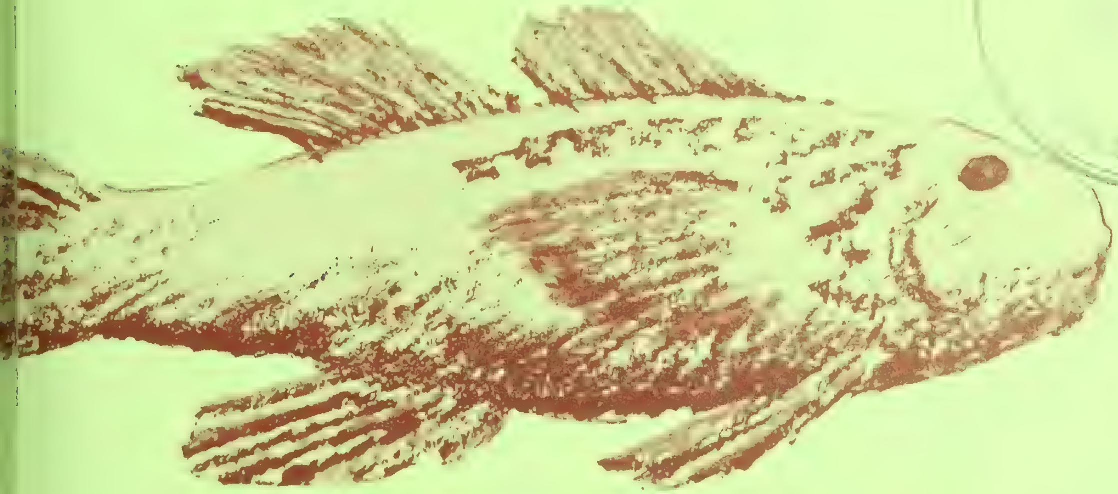
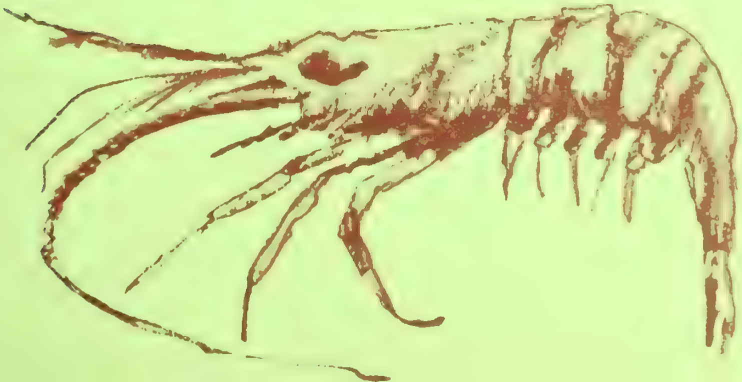
Water and the Ecosystems of the Luquillo Experimental Forest

Ariel E. Lugo

An Institute of Tropical Forestry Publication

S DOCUMENTS





Water and the Ecosystems of the Luquillo Experimental Forest

Ariel E. Lugo

INTRODUCTION

Water is an essential requirement of all living systems. At the cellular level water is needed to maintain cell turgidity and to serve both as a medium and reactant in metabolic processes. On a larger scale, water is critical for transporting materials through plants, animals, and watersheds, and for regulating the temperature of these systems. As water flows to the ocean, it performs many functions for organisms and the landscape, and its value (or its ability to do work) changes in relation to its elevation and its quality (Odum 1970a). The rate of organic matter production and accumulation in tropical forest ecosystems is a function of net water availability, e.g., rainfall minus potential evapotranspiration (Brown and Lugo 1982). Furthermore, Holdridge (1962, 1967) showed water availability to be a regulating factor in the complexity of forest structure. Estuarine productivity and biotic composition are also influenced by freshwater runoff from upland ecosystems (Carter et al. 1973).

Because the amount of water available to any sector of the biosphere is essentially controlled by rainfall and condensation, and because human demands for water are increasing in disproportion to local water supplies, resource managers are required to allocate water-use priorities among competing consumers. Typically, natural ecosystems are not considered legitimate users of water unless a particularly valuable ecosystem is involved. For example, laws in the state of Florida assure a minimum water supply to the wetlands of Everglades National Park, regardless of water shortages in the city of Miami. The water rights of the ecosystems of the Everglades are recognized as legitimate in that state. In other places, however, water flow to the ocean is viewed as a waste of freshwater. Such a view ignores the importance of freshwater to estuaries, coastal swamps, alluvial valleys, and floodplains. The water rights of natural ecosystems are often unrecognized.

This paper review facts about water dynamics, water balance, and water requirements of the ecosystems and aquatic organisms of the Luquillo Experimental Forest (LEF), also known as the Caribbean National Forest. These ecosystems need water to leach plant and soil surfaces, to sustain organic productivity and evapotranspiration, and to maintain stream functions involving flora, fauna, and fluvial processes. The objective of this paper is to draw attention to research needs on this subject and to highlight the importance of freshwater allocations to natural ecosystems. The need for such water allocations has become relevant in Puerto Rico where the Department of Natural Resources (DNR) is currently granting water-use rights as part of regulations that implement the 1976 Water Resources Act.

WATER DYNAMICS AND WATER BALANCE

Rainfall and Condensation

Annual rainfall in the Luquillo Mountains increases with elevation (fig. 1) from 2460 mm in Rio Blanco to 4700 mm at La Mina. Values as high as 6450 mm have been measured at La Mina at 716 m elevation and as low as 1000 mm at Rio Grande, El

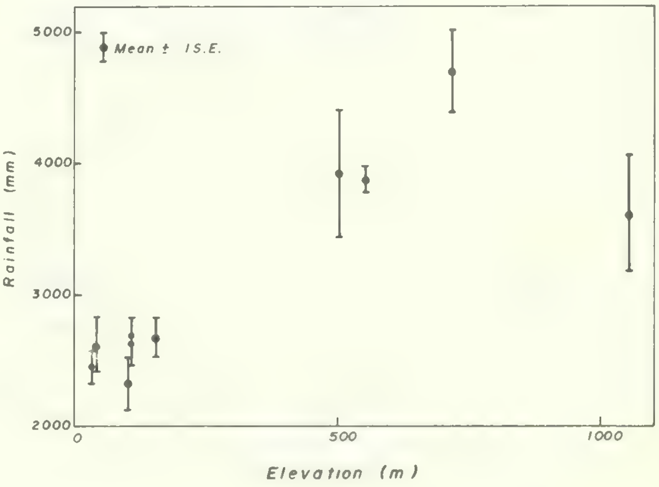


Figure 1.—*Variation of mean annual rainfall with elevation in the Luquillo Experimental Forest. Data are from table 1 (Brown et al. 1983).*

Ariel E. Lugo is research ecologist/project leader for the Southern Forest Experiment Station's tropical American forest management program t Rio Piedras, Puerto Rico.

Table 1.—*Mean annual rainfall and station descriptions for stations within and adjacent to the Luquillo Experimental Forest (Brown et al. 1983)*

Station	Elevation (m)	Location lat/long °N/°W	Years of record	Mean rainfall (cm)	C.V.[§] (%)	S.E.[ξ]
Río Blanco 1	30.5	18°15′/65°47′	12	246	15	11
Río Blanco 2a	40	18°15′/65°47′	16	263	31	20
Paraiso	101	18°16′/65°43′	43	233	19	7
Río Grande El Verde	107	18°21′/65°49′	20	264	30	18
Río Grande El Verde	107	18°21′/65°49′	21	267	28	16
Río Blanco 3	152	18°15′/65°47′	18	268	23	15
El Verde	500		7	392	33	49
Río Blanco 4	549	18°18′/65°47′	27	387	13	10
La Mina	716		8	470	19	32
Pico del Este	1,051	18°16′/65°45′	9	360	38	46

[§] Coefficient of variation (C.V.) = $\frac{\text{(Standard deviation)}}{\text{mean}} \times 100$

[ξ] Standard error of the mean.

Table 2.—*Total rainfall and evapotranspiration by elevation in the Luquillo Experimental Forest and vicinity*

				Total	
Elevation	Area[§]	Rainfall[ξ]	Evapotranspiration	Rainfall	Evapotranspiration
M	*Ha*	----------- *M/yr* -----------		---- *Cubic hectometers/yr* ----	
122–305	5,091	2.9	2.66	147.64	135.42
305–610	9,106	3.8	1.82	346.03	165.73
610–915	4,897	4.6	0.90	225.26	44.07
>915	554	4.1	0.40	22.71	2.22
Total	19,648	3.775*	1.77*	741.64	347.44

[§] Wadsworth 1949.

[ξ] Brown et al. 1983 and fig. 1.

*Weighted average.

Table 3.—*Total rainfall and evapotranspiration by forest type in the Luquillo Experimental Forest*

				Total	
Forest type	Area[§]	Rainfall[§]	Evapotranspiration	Rainfall	Evapotranspiration
	Ha	----------- *M/yr* -----------		---- *Cubic hectometers/yr* ----	
Tabonuco	5,657	3.0	1.76[ξ]	169.71	99.56
Colorado	3,285	4.0	0.83[†]	131.40	27.27
Palm	1,914	3.7	0.83[†]	70.82	15.89
Dwarf	412	4.5	0.16[α]	18.54	0.66
Total	11,269	3.465[√]	1.272[√]	390.47	143.37

[§] U.S.D.A. Forest Service 1984.

[ξ] Odum 1970c.

[†] Frangi and Lugo 1985.

[α] Brown et al. 1983.

[√] Weighted average.

Table 4.—*Total rainfall and evapotranspiration by life zone in the Luquillo Experimental Forest*

Life zone[§]	Area[ξ]	Rainfall[α]	Evapotranspiration[α]	Total Rainfall	Total Evapotranspiration
	Ha	*M/yr*	*M/yr*	*Cubic hectometers/yr*	*Cubic hectometers/yr*
Moist	216	1.6	1.279	3.46	2.76
Wet	4,043	3.0	1.76	121.29	71.16
Rain	1,398	4.66	1.259	65.15	17.60
Lower montane wet	4,331	2.863	1.14	124.00	49.37
Lower montane rain	1,280	4.533	1.096	58.02	14.03
Total	11,269	3.3*	1.375*	371.91	154.92

[§] All subtropical forest.

[ξ] U.S.D.A. Forest Service 1984.

[α] Ewel and Whitmore 1973.

*Weighted mean.

Verde at 152 m elevation (fig. 2). The coefficient of variation for annual rainfall ranges from 13 to 38 percent without relation to elevation (table 1). While rainfall is fairly evenly distributed year-round, particularly at lower elevations, rainfall is lower in the months of February, March, and April and higher in May or October, depending on elevation (Brown et al. 1983). Holben et al. (1979) found that a network with 2.3–3.1 rain gauges/km^2 was needed to construct 254 mm rainfall isopletes in the Espiritu Santo watershed of the LEF.

I calculated the total annual rainfall in the LEF using three methods: 1) from a relation between ele-vation and rainfall (fig. 1) multiplied by the area at each elevation interval (table 2); 2) multiplying the area of major forest types by the average rainfall re-ported for each type (table 3); and 3) multiplying the area of life zones (*sensu* Ewel and Whitmore 1973) by he mean annual rainfall for stations in that life zone table 4). In all cases total rainfall was divided by the rea of the LEF to obtain a weighted rainfall ex-ressed in depth units (mm). Results show a range of 300 mm to 3775 mm in the estimated mean annual ainfall (tables 2–4). A mean of the three estimates 3513 mm) yields 395.88 cubic hectometers of water ver the LEF. Research has shown that amounts of up o 10 percent of rainfall are condensed from clouds in he cloud forest (Baynton 1968, 1969; Weaver 1972). t lower elevations (500 m), condensation accounts or 4 percent of rainfall (Odum et al. 1970). Because at ower elevations this water quickly evaporates, I ig-nored this input in the analysis. Using an average ainfall of 4400 mm/yr for the cloud forest (tables 2–4) nd the area of cloud forest (table 3), I calculated that n additional 1.85 cubic hectometers of water are vailable to the LEF through condensation. Adding his amount to the mean rainfall results in a total nnual water input to the LEF of 397.73 cubic hec-meters (3529 mm).

Evapotranspiration

Evapotranspiration includes two processes: water evaporation from free surfaces (soil, plant, and water) and transpiration. Odum (1970b) demonstrated that evapotranspiration in the LEF decreased with increasing elevation because of the decrease in atmospheric saturation deficit. Odum hypothesized that the rate of evapotranspiration possible at any given elevation influenced such forest properties as vegetation height, physiognomy, nutrient uptake, foliar morphology and orientation, and the number, biomass, and distribution of roots.

I calculated the total annual evapotranspiration in the LEF using three methods: 1) from a relation ($y = -0.32\ x + 332$; $r^2 = 0.99$, $n = 3$) between elevation (x in m) and evapotranspiration (y in cm) multiplied by the area at each elevation interval (table 2); multiplying the area of major forest types by the average evapotranspiration for the type (table 3); and 3) multiplying the area of life zones (table 4) by the evapotranspiration of the life zone calculated by the method in Ewel and Whitmore (1973).

The estimated annual evapotranspiration of the LEF was 143.37 cubic hectometers or 1272 mm. This is equivalent to 35 percent of the estimated annual water input. The life zone method resulted in higher values (154.92 cubic hectometers, 1375 mm, and 42 percent, respectively; table 4). Higher values were also obtained using the relation of evapotranspiration with elevation (table 2). The mean annual evapotranspiration estimate based on the three methods is 1472 mm or 42 percent of the total water input to the LEF.

Runoff

Nine rivers have their headwaters in the LEF (fig. 3). Mean annual discharge is directly related to elevation of a gauging station (table 5). Variation in

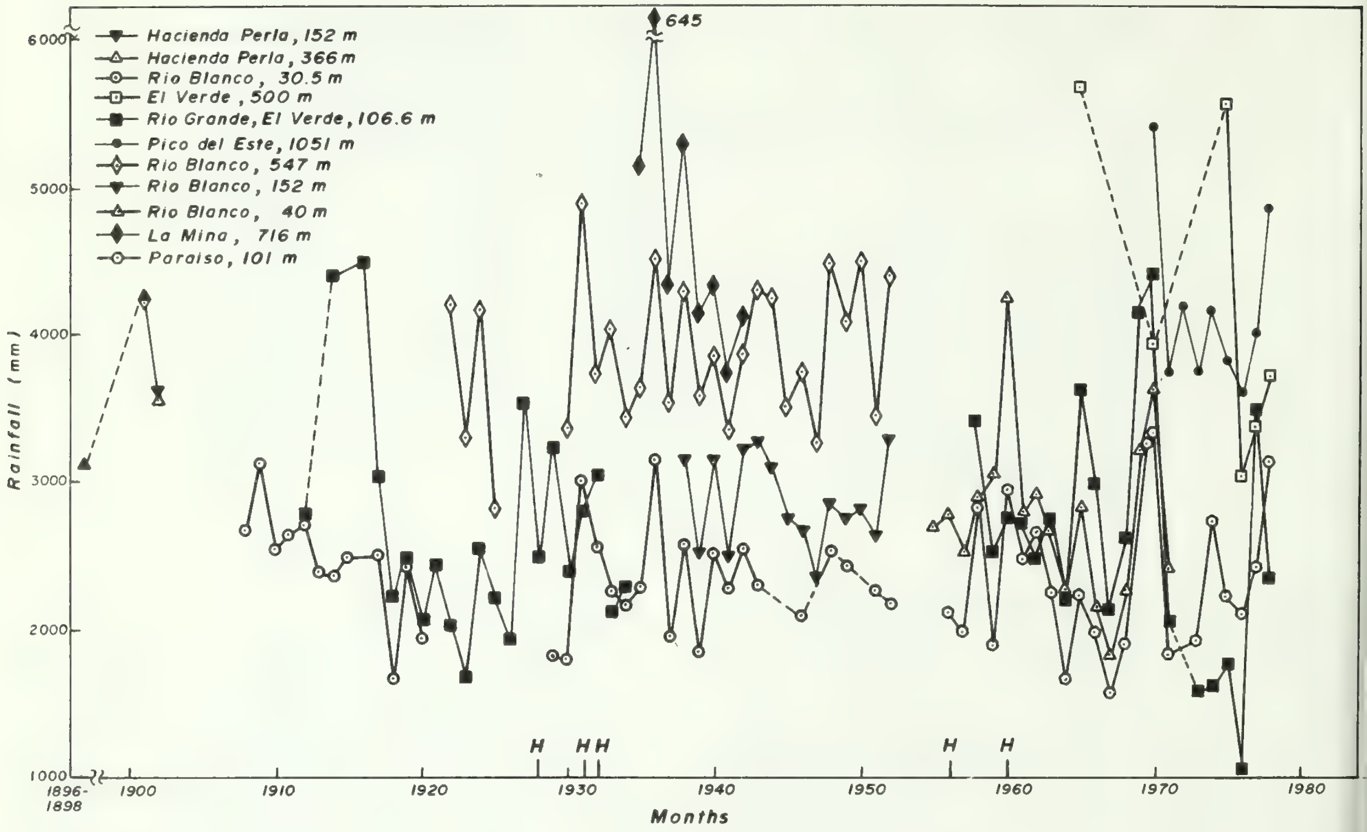


Figure 2.—*Patterns of annual rainfall for stations in and adjacent to the Luquillo Experimental Forest (U.S. Department of Agricultu 1909–1913, 1915–1921, 1921–1939; U.S. Department of Commerce 1940–1952, 1955–1979; Wilson 1899). From Brown et al. 198*

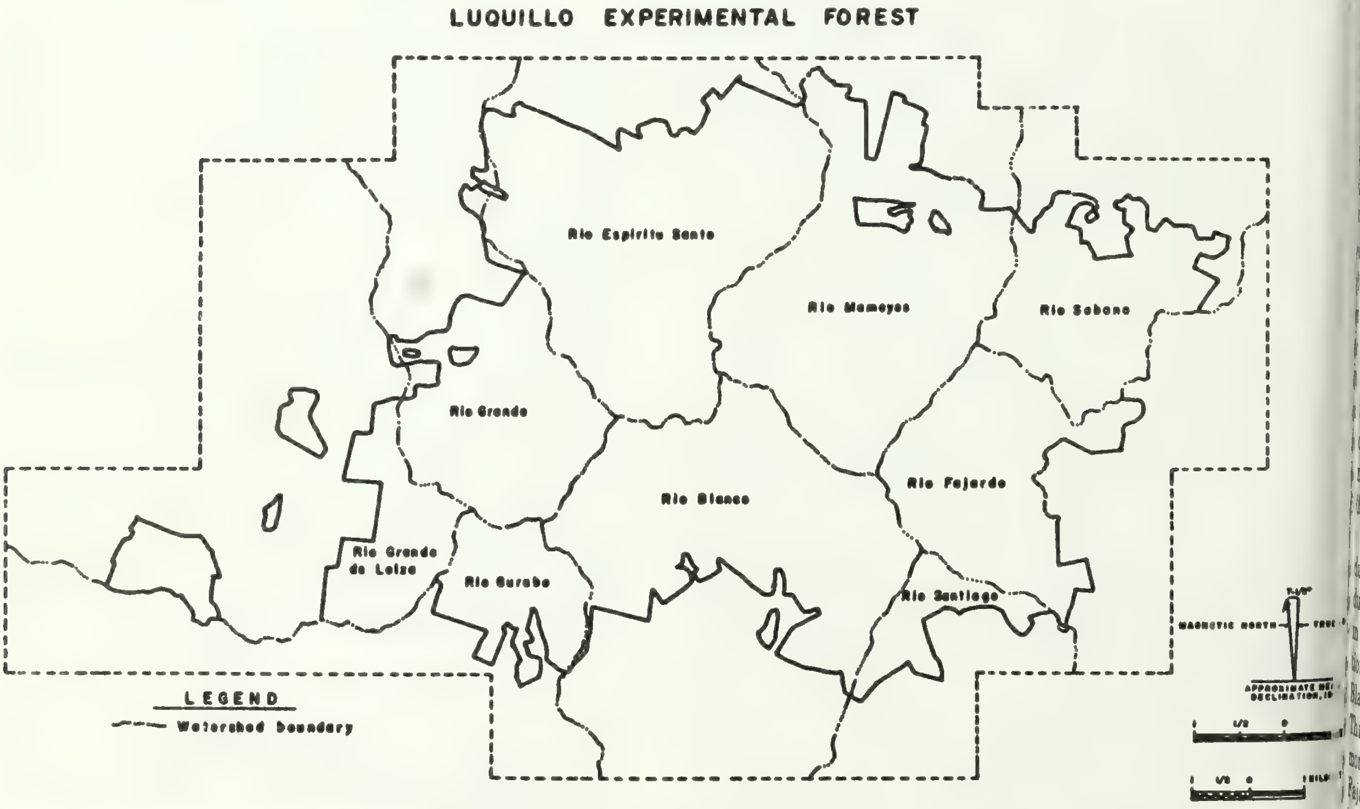


Figure 3.—*Location of watersheds in the Luquillo Experimental Forest (Brown et al. 1983).*

Table 5.—*Station description and mean annual discharge for stream gaging stations within and adjacent to the Luquillo Experimental Forest. Values in parenthesis based on Quiñones et al. 1984*

Station	I.D. No.[§]	Elevation	Latitud °N	Longitud °W	Period of record	Mean annual discharge	S.E.[ξ]	C.V.[α]
		M			*Yr*	*Cm*		*%*
Río Espíritu Santo Basin								
Río Espíritu Santo near El Verde	633	515	18°19′	65°49′	6	469 (426)	45	23
Río Grande near El Verde	642	38	18°21′	65°50′	8	268 (196)*	42	45
Río Espíritu Santo near Río Grande	638	12	18°22′	65°49′	10	214 (220)†	20	29
Río Mameyes Basin								
Río Mameyes near Sabana	655	84	18°20′	65°45′	6	300 (282)	44	36
Río Mamayes at highway 191	657	7	18°22′	65°46′	17	197†		
Río Sabana Basin								
Río Sabana at Sabana	670	80	18°19′	65°43′	4	145†		
Río Fajardo Basin								
Río Fajardo near Fajardo	710	42	18°17′	65°41′	22	141†		
Río Blanco Basin								
Río Blanco	770	15	18°13′	65°46′	9	189*		

[§] U.S. Geological Survey identification, numbers shown are preceeded by 500 and followed by 00.
[ξ] Standard error of the mean.
[α] Coefficient of variation (C.V.) = (standard deviation/mean) × 100.
*Based on 1973 discharge.
†Based on flow duration data, Quiñones et al. 1984.

Table 6.—*Relations between rainfall (x) and stream runoff, stemflow, and throughfall at 750 m elevation in the Luquillo Experimental Forest (Frangi and Lugo 1985). All values are in mm except runoff (mm/week)*

Y Parameter	Equation	r^2
Runoff	$\ln y = 3.07 + 0.01x$	0.89
Stemflow	$y = 0.10x - 0.09$	0.95
Throughfall	$y = 0.86x - 1.29$	0.98

nnual discharge, measured by the coefficient of variation, was lowest for the highest and lowest elevation stations. The pattern of annual water discharge is similar for all stations, but the magnitudes are different (fig. 4). Most streams for the 2 consecutive years 1969 and 1970 had unusually high flows. This was due to high rainfall induced by stationary northern fronts and tropical depressions (Brown et al. 1983).

Mean monthly discharge decreases from high to low elevations. Peaks of flow coincide with rainfall peaks (fig. 5a). Frangi and Lugo (1985) reported a logarithmic relation between rainfall and stream discharge and linear ones between rainfall and stemflow and throughfall at 750 m elevation (table 6). Apparently most of the rainfall at high elevations, particularly during intense storms, finds its way to stream channels and causes typical fluctuations in stream stage (fig. 6a).

Most variability in river discharge was recorded during the months of peak discharge (fig. 5). Flow duration curves (fig. 7) illustrate monthly variations in river discharge as a function of aspect and elevation. Large month-to-month variations typify the Rio Blanco on the drier south side of the forest (fig. 7a). This river exhibits both the lowest and highest monthly base flows in the LEF. In contrast, the Rio Fajardo (fig. 7b), located on the humid eastern boundary of the forest, exhibits little month-to-month variation in discharge. Changes with elevation are illustrated with the three flow duration curves for Rio Espiritu Santo (fig. 7c–e). There is less variation at higher elevations that at the low elevation stations. Rio Grande (fig. 7f) and Rio Mameyes (fig. 7g) have high rates of discharge with little monthly variation, while the Rio Sabana (fig. 7h) has low rates of discharge and high month-to-month variability of flow.

Runoff is the difference between water input (rainfall and condensation) and evapotranspiration. From tables 2, 3, and 4, annual runoff is estimated to be between 1941 and 2209 mm (mean of 2052 mm). These estimates can be verified by independent measurements of stream discharge by the U.S. Geological Survey (USGS). However, the USGS gauges are usually located at lower elevations outside or just at the boundary of the LEF.

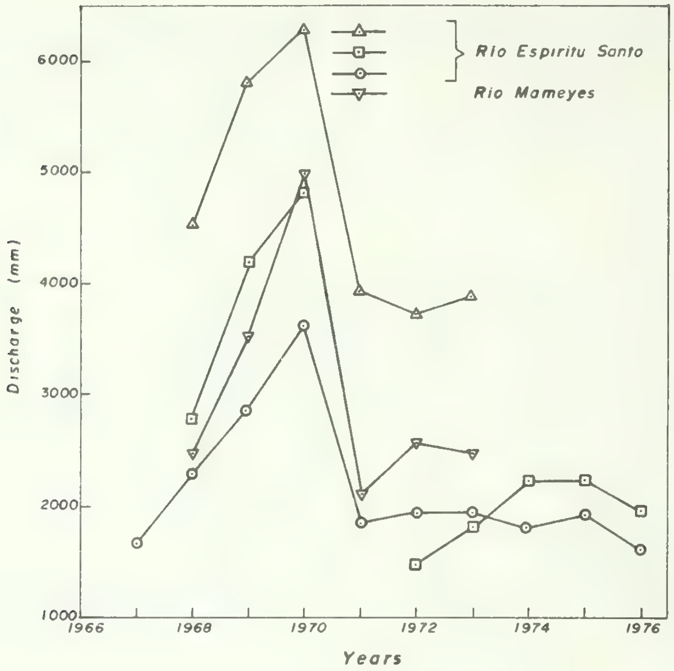


Figure 4.—*Annual stream discharge for rivers draining the Luquillo Experimental Forest (U.S. Department of Interior 1967, 1968–1977). From Brown et al. 1983.*

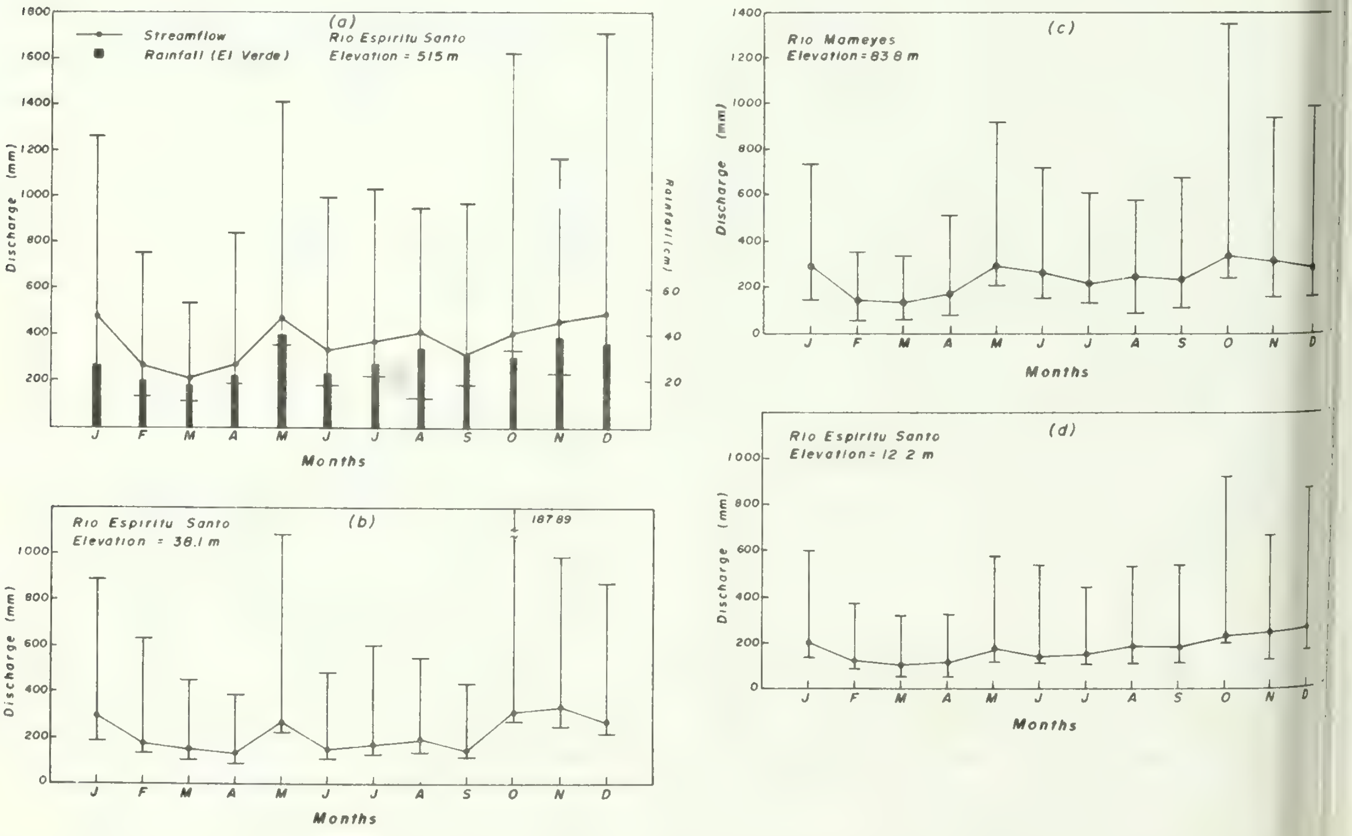


Figure 5.—*Mean range of monthly discharge from rivers draining the Luquillo Experimental Forest (U.S. Department of Interior 19 1968–1977). From Brown et al. 1983.*

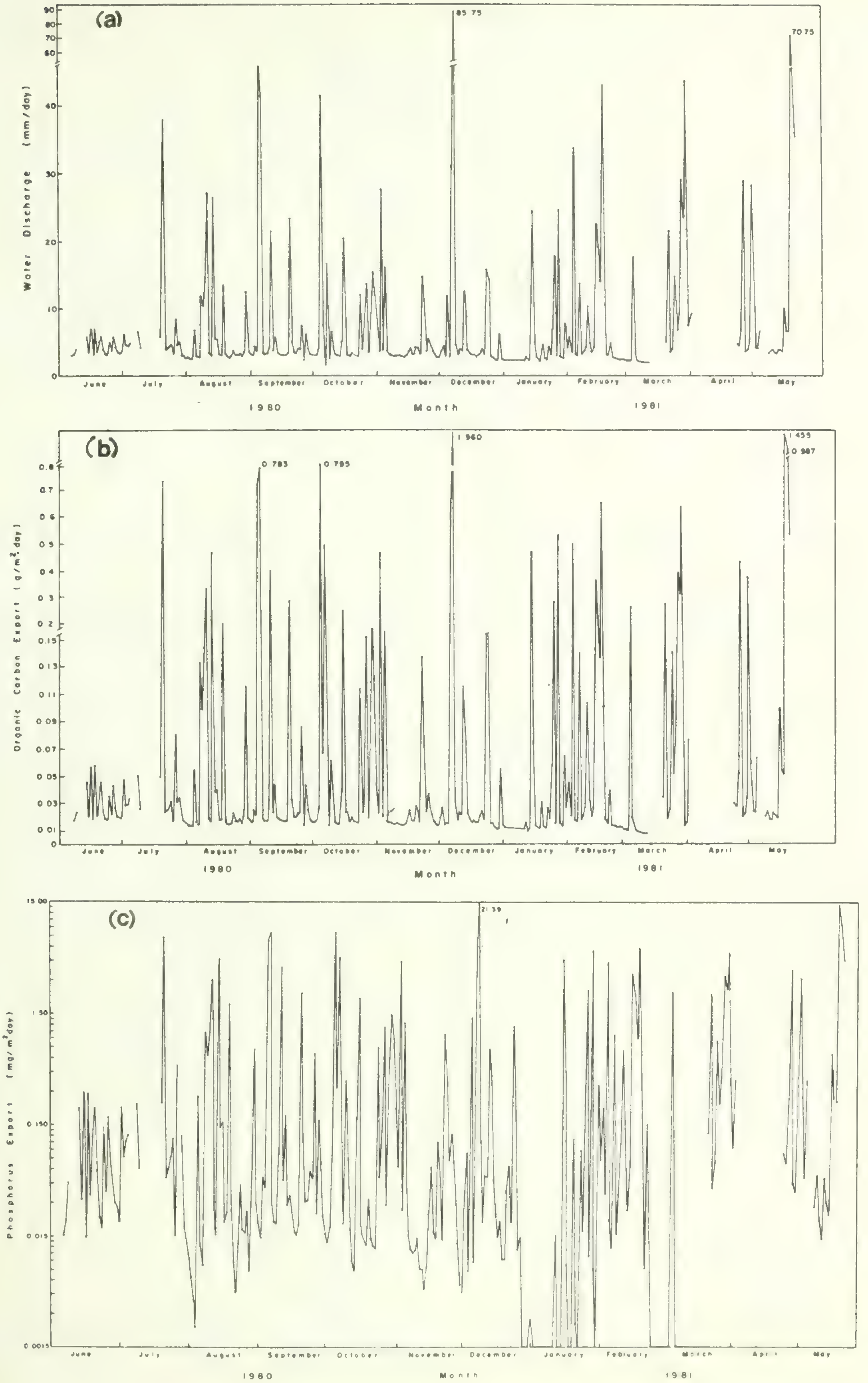


Figure 6.—*Daily water (a), carbon (b), and phosphorus (c) discharge of the Rio Espiritu Santo at 750 m elevation (Frangi and Lugo 1985).*

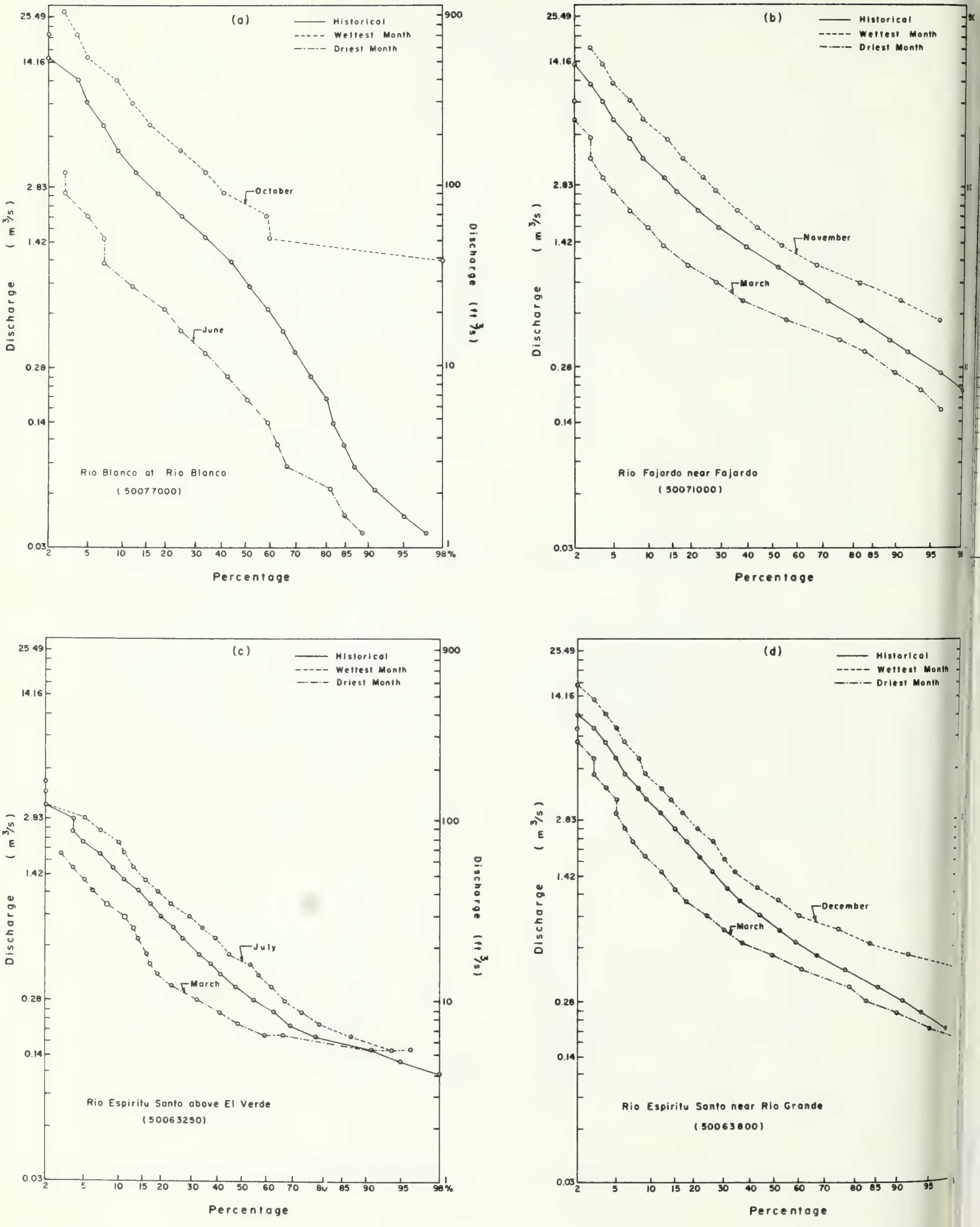
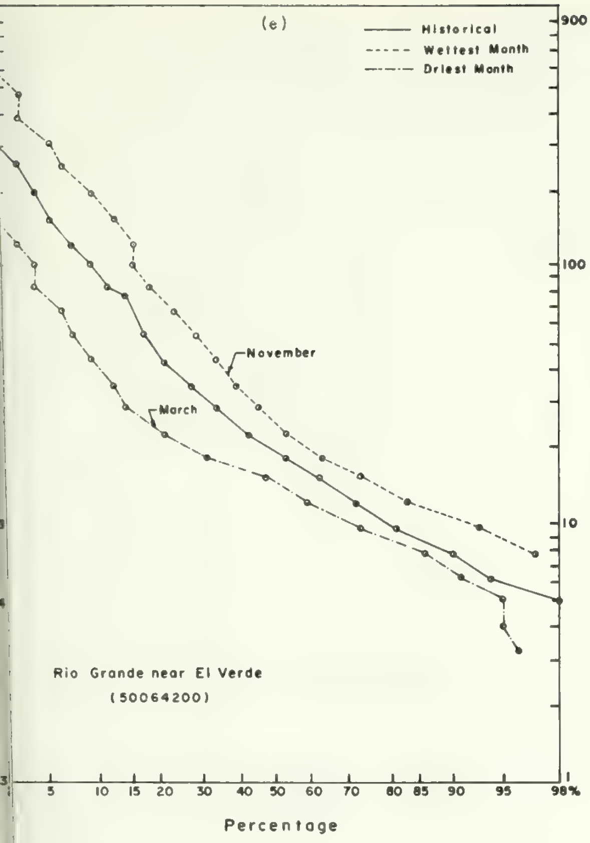
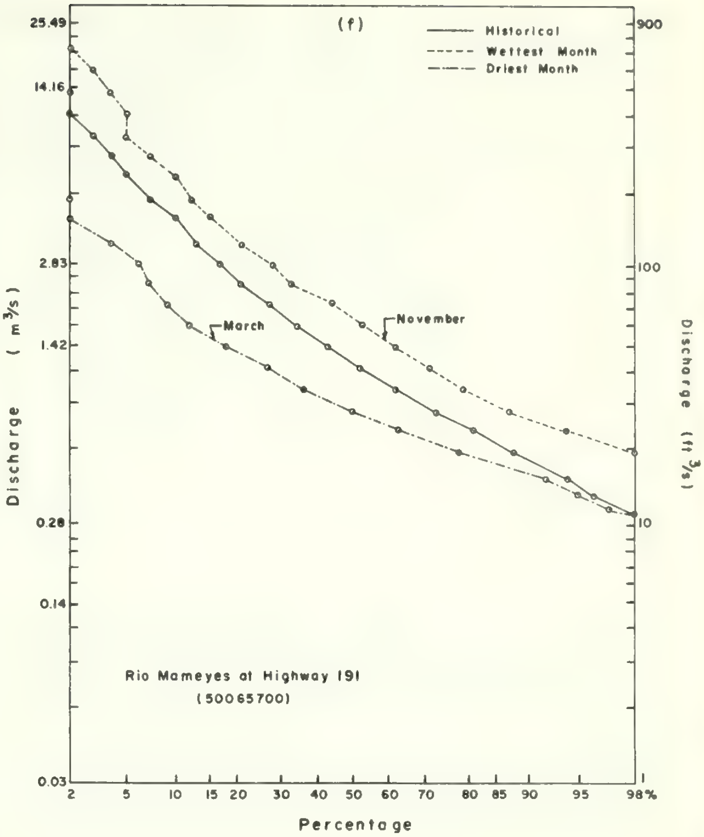


Figure 7.—*Flow-duration curves for rivers draining the Luquillo Experimental Forest. Historical average and the months with maximum and minimum flows are shown. Data are from Quiñones et al. 1984.*


(e)
Historical
Wettest Month
Driest Month
November
March
Rio Grande near El Verde
(50064200)
Discharge (ft³/s)
900
100
10
1
5
10
15
20
30
40
50
60
70
80
85
90
95
98%
Percentage


(f)
Historical
Wettest Month
Driest Month
November
March
Rio Mameyes at Highway 191
(50065700)
Discharge (m³/s)
25.49
14.16
2.83
1.42
0.28
0.14
0.03
Discharge (ft³/s)
900
100
10
2
5
10
15
20
30
40
50
60
70
80
85
90
95
98%
Percentage

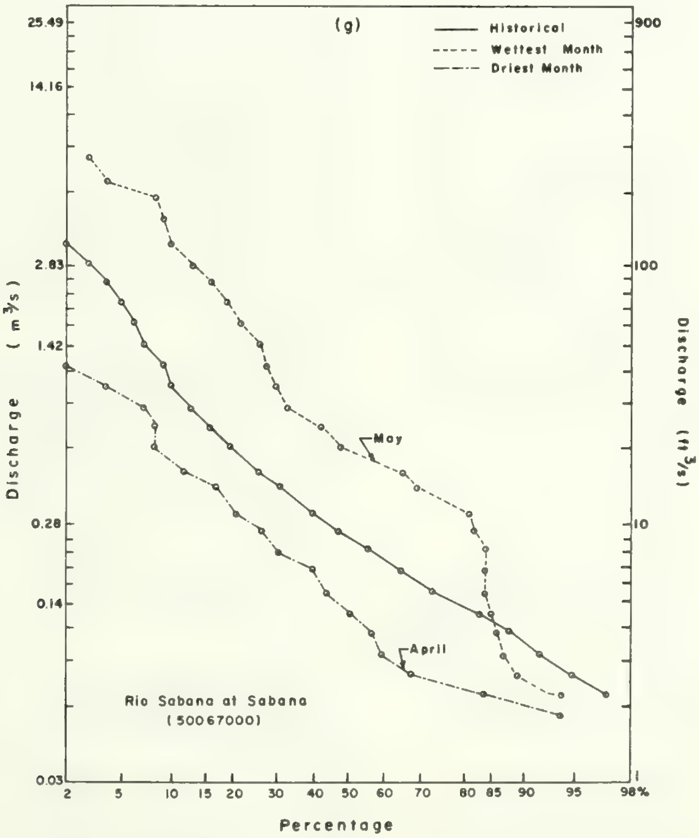

(g)
Historical
Wettest Month
Driest Month
May
April
Rio Sabana at Sabana
(50067000)
Discharge (m³/s)
25.49
14.16
2.83
1.42
0.28
0.14
0.03
Discharge (ft³/s)
900
100
10
1
2
5
10
15
20
30
40
50
60
70
80
85
90
95
98%
Percentage

Table 7.—*Runoff and total water discharge from the Luquillo Experimental Forest and vicinity*

Watershed	Area[§]	Runoff[α]	Total discharge
	Ha	*Cm/yr*	*Cubic hectometer/yr*
Espíritu Santo	4,977	220	109.49
Grande de Loíza	4,753	196*	93.16
Mameyes	2,465	197	48.56
Sabana	1,609	145	23.33
Fajardo	2,053	141	28.95
Blanco	3,791	189*	71.65
Total	19,648	190.9[†]	375.14

[§] Wadsworth 1949.

[α] Quiñones et al. 1984.

*Based on 1973.

[†] Weighted average.

The USGS-derived estimate of runoff was calculated by multiplying the area of watersheds (table 7) be the mean annual discharge of each watershed. Mean annual discharge was obtained from flow duration curves (fig. 7) according to the method of Miller (1951). For two watersheds without flow duration curves, I used mean flow for 1973, a year of "typical" flow (fig. 4). The measured annual water runoff out of the LEF is 375.14 cubic hectometers or 1909 mm (table 7). This value is within 7 percent of the mean estimate based on the three methods discussed above (tables 2–4). The life zone estimate (table 4) was even closer (within 2 percent of the measured amount).

Previous studies show that the fraction of rainfall that appears as runoff ranges widely in different sectors of the LEF (table 8). As elevation increases, more rainfall appears as runoff (from 52 percent at 500 m to 95 percent at 1,000 m elevation). The runoff estimate using elevation, forest types, and life zone result in >58 percent of rainfall as runoff reflecting the strong influence of high elevation forests. The estimate based on the USGS network shows 54 percent of the rainfall as runoff, a value closer to the results obtained at 500 m elevation (52 percent). This reflects the low elevation location of gauging stations.

WATER QUALITY

Rainfall in the LEF is slightly acid (average pH = 5.51; n = 27; Trinidad Pizarro 1985) and relatively rich in salts of marine origin (Odum 1970c). The pH of clouds (5.19; Trinidad Pizarro, personal communication, December 1985) that pass over the forest at 1,000 m elevation is lower than that of rainfall; their chemical composition is variable but nutrient and element concentrations are higher than those of rainfall. For example, preliminary data collected by Trinidad Pizarro in a cooperative study with the Institute of Ecosystem Studies in New York (K.C. Weathers, Personal communication, February, 1986) showed that the mean concentrations (mg/l in parenthesis) of Ca (4.3), Mg (2.1), K (1.0), Na (14.7), NH4 (0.5), SO4 (10.5), NO3 (4.9), and Cl (25.3) were (respectively) 4.3, 3.5, 1.3, 2.8, 1.7, 3.8, 8.2, and 2.8 times higher in cloud (n = 7) than in rain (n = 14) water samples collected simultaneously. The chemistry of cloud water was more variable than that of rain water.

The factors that influence the chemical composition of clouds and rain in the LEF include wind direction, time of year, and land use in the lowlands. The mechanisms and details of the interaction of these factors are largely unknown. However, it is known that northern winter winds are associated with storms rich in marine salts (Odum 1970c), which affect forest stands on northern exposures. During the dry season, southern winds cause similar events over forests on south-facing slopes. These winds transport dust from the African continent. Burning of lowland agricultural fields on the eastern and southern boundaries of the forest also influences the quality of clouds passing over the LEF.

Riverine waters are usually oligotrophic (table 9) with little diurnal (McDowell 1984) and monthly (Cuevas and Clements 1975; McDowell 1984) variation in nutrient concentrations. Because of the high inputs of salt spray, rivers in the LEF have high sodium and chlorine concentrations. At higher elevations (>700 m) stream waters transport high quantities of organic carbon and phosphorus (Frangi and Lugo 1985; fig. 6b and c). Natural populations of the fecal indicators *Escherichia coli* and *Bifidobacterium adolescentis* have been found in these waters where no human influence can be found (Carrillo et al. 1985). Continuously saturated soils at high elevations play important roles in maintaining high organic matter in streams and possibly in the support of the fecal bacteria.

The amount of dissolved solids transported by rivers in the LEF is directly related to river discharge (fig. 8). However, the waters at higher elevation transport less solids than those at lower elevations in spite of the differences in water discharge (table 10). High elevation forests appear to be efficient in maintaining high water quality.

SPECIALIZED AQUATIC HABITATS

In addition to rivers, streams, bogs, and floodplain and slope wetlands, the LEF harbors many small, highly specialized aquatic habitats that support a variety of freshwater organisms. These habitats include tank bromeliads, supersaturated and highly decomposed woody tissue, tree cavities, rock crevices, and saturated soils. With the exception of some preliminary work on the aquatic ecosystems that develop in

Table 8.—*Summary of water budgets for the Luquillo Experimental Forest. Percent of rainfall in parenthesis*

Calculation based on:	Rainfall and condensation	Evapotranspiration	Runoff
	Mm/yr		
Elevation	3,791	1,770 (42)	2,021 (58)
Forest types	3,481	1,272 (37)	2,209 (63)
Life zone	3,316	1,375 (41)	1,941 (59)
River gages	3,529	1,620 (46)	1,909 (54)
Odum et al. (1970) at 500 m elevation		(48)	(52)
Bogart et al. (1964) at 600 m elevation		(15)	(85)
Frangi and Lugo (1985) at 750 m elevation		(22.3)	(77.7)
Baynton (1968, 1969) at 1000 m elevation		(5)	(95)

b 9.—*Mean water quality parameters of rivers and streams draining the Luquillo Experimental Forest. Data are for the period 1969–1974 (U.S. Department of Interior, Geological Survey, 1968–1977 and for 1983–1984). One standard error is given in parenthesis*

arameter	Río Espíritu Santo (515 m)* (n = 31)	Río Mameyes, Sabana (84 m)* (n = 34)	Río Grande El Verde (38 m)* (n = 12)	Río Espíritu Santo (12 m)* (n = 15)	Quebrada° Sonadora°	Río° Icacos°	Quebrada° Toronja°
erature (C)	21.4 (0.5)	22.9 (0.2)	24.8 (0.7)	24.7 (0.7)			
ic conductance cro mhos)	56.6 (2.9)	85.3 (17.1)	107.9 (6.5)	184.9 (95.2)	40	49	91
	6.9 (0.09)	7.2 (0.10)	7.5 (0.10)	7.1 (0.11)			
inity (mg/l)	14.1 (1.7)	32.8 (2.7)	39.5 (3.2)	23.7 (6.5)			
g/l)	3.9 (0.3)	10.5 (0.4)	8.6 (0.7)	6.6 (0.8)	2.2	3.0	5.6
ng/l)	1.7 (0.1)	2.5 (0.03)	4.2 (0.3)	3.0 (0.5)	1.5	1.2	4.6
g/l)	5.6 (0.1)	6.7 (0.2)	8.5 (0.4)	6.8 (0.4)	4.2	4.6	6.6
/l)	0.42 (0.05)	0.60 (0.04)	0.43 (0.02)	0.40 (0.02)	0.25	0.52	0.28
g/l)	7.7 (0.1)	8.4 (0.2)	10.3 (0.4)	9.1 (0.6)	6.6	5.7	7.9
ng/l)	2.2 (0.2)	4.0 (0.4)	2.5 (0.3)	2.6 (0.3)			
mg/l)	0.23 (0.07)	0.20 (0.05)	0.10 (0.03)	0.01 (0.01)	0.05	0.07	0.07
ved (mg/l)	0.05 (0.03)	0.30 (0.3)	0.04 (0.04)	0.03 (0.02)	0.002	0.003	0.006
mg/l)					8.5	14.2	20.5
ents (mg/l)					7.5	36.7	8.5

*Elevation.

°Flow-weighted means from McDowell 1984.

Table 10.—*Water and dissolved solid discharge by two rivers in the Luquillo Experimental Forest (Brown et al. 1983)*

River and station	Discharge: Water	Discharge: Solids	Elevation
	Cm	*T/yr*	*M*
Río Espíritu Santo			
633	469	953	515
638	214	2,320	12
Río Mameyes	300	3,324	84

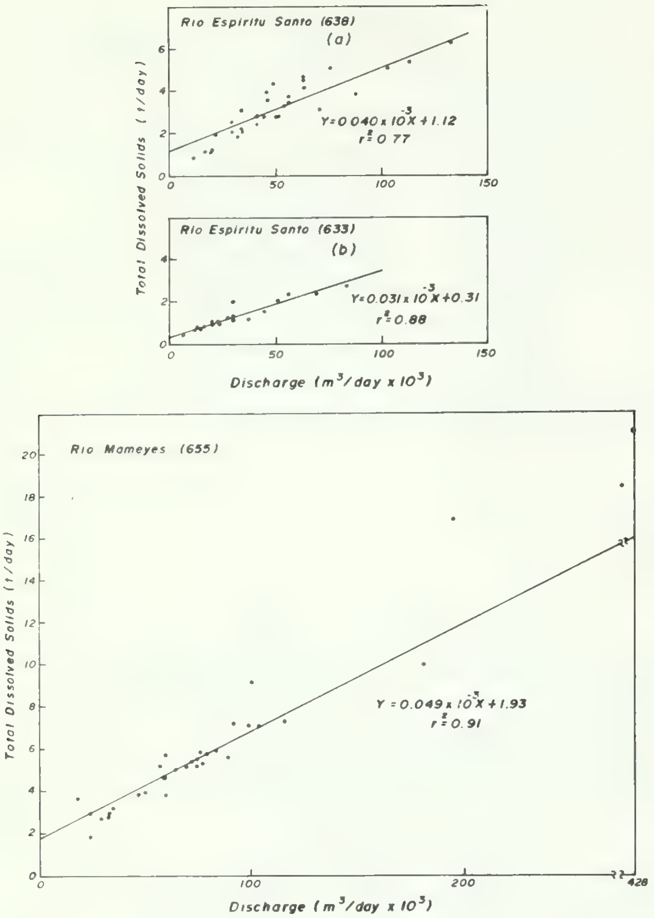


Figure 8.—*Relationship between stream discharge and the export of total dissolved solids (U.S. Department of Interior 1968–1976) From Brown et al. 1983.*

tank bromeliads (Maguire 1970), very little research has been conducted in these habitats. However, these habitats may prove to be critical links to the larger aquatic environments and perhaps even to estuarine systems in the lowlands.

LINKS BETWEEN AQUATIC HABITATS INSIDE AND OUTSIDE THE FOREST

Brown et al. (1983) described the ways the forests of the LEF are finely tuned to variations in moisture availability. They also listed those characteristics of forests that minimize the negative (stressful) effects of too much water while taking advantage of the availability of moisture (table 11). This "push-pull" effect of water on forests, the altitudinal arrangement of forest types with increasing rainfall, and the complex flow of water through a forest stand (fig. 9) leave no doubt as to the overriding importance of water to the ecosystems of the LEF. However, about 58 percent of the rainfall leaves the forest boundary as runoff (tables 7 and 8). To what extent does the water that flows to the ocean from the LEF contribute to the maintenance of biotic activity in the LEF? To addres this question, it is necessary to know how the ecosystems of the LEF are related to downstream ecosystems and to what degree that dependency is itsel dependent on freshwater runoff.

Many animal species in the LEF are known to depend on runoff for survival (table 12). A survey of th Espiritu Santo River reported 10 decapod crustaceans, 9 species of shrimp, one species of crab 5 orders of drifting insect larvae, and 2 species of fish from forested areas of the watershed (Bhajan et al 1980). Two additional species of freshwater fish may inhabit rivers in the lower elevations of the fores (Corujo Flores 1980). Altitudinal ranges of these species are given in fig. 10. Bhajan et al. (1980) verified the estuarine dependence of larval phases of severa species of freshwater shrimp. Seven of these species are seasonally commercial and are considered vulnerable by the DNR. Canals (1979a) documented the estuarine dependence of another freshwater shrimp species (*Macrobrachium crenulatum*) in the Rio Espiritu Santo. Other species in this genus exhibited the fastest development at a salinity of 16 percent (Villamil and Clements 1976). Fairly detailed studies of the habitat relationships of four freshwater shrimp species in the same watershed were conducted by Villamil and Clements (1976). Intraspecific habitat selection in *Atya lanipes* (fig. 11) result in male predominance in high flow areas and females in lower flow areas with rubble and gravel substrate.

The only freshwater crab in Puerto Rico (*Epilobocera situatifrons*) utilizes both land, where it burrows in stream banks, and aquatic habitats, to which the young are restricted. The species feeds on decaying material. Stream invertebrates are important year-round consumers of forest leaf litter (Covich 1985a). For example, caddisfly larvae (*Phylloicus pulchrus* use leaves from 20 species of trees, decapod shredders include juvenile potamonid crabs (*E. situatifrons*) atyid shrimp (*Xiphocaris elongata* and *A. lanipes*) and palaemonid shrimp (*M. carcinus, M. crenulatum, M heterochirus*). Numerically dominant consumers such as *Atya* and *Xiphocaris* feed on a wide variety o leaves, fruits, flowers, and periphyton. *Atya lanipes* filter out suspended microflora and leaf fragments during high flow and scrapes the microflora from decomposing leaves at lower water flows.

Sicydium plumieri, the gobiid fish, also has a marine phase. Eggs are laid under rocks in freshwater from May to October and are washed to sea during heavy rains. Larvae return one month later to migrate upstream. The post larvae or seti are a food delicacy, caught as they enter the river mouth in a massive red-silver ball (Erdman 1961).

Three frog species also depend on runoff for survival. The introduced *Bufo marinus* requires still water pools for reproduction, *Eleutherodactylus* le 11.—*Examples of forest responses to water in the Luquillo Experimental Forest (Brown et al. 1983)*

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ee growth, seed germination, explosive seedling growth, leaf fall, flowering and fruiting are all synchronized to slight changes in
infall, which was documented in El Verde.
omeliads and other epiphytic organisms store water within their leaves and large and diverse populations of animals utilize these as
bitats and for reproduction.
p roots, abundance of deciduous species, and tree growth rings, which are normal responses to moisture seasonality, are not usual
tures in the forests of the Luquillo Mountains.

Adaptations That Minimize the Impacts of Too Much Water Are:

iphytic coverage of surfaces increases with increasing moisture which in turn, contributes to an even distribution of through-fall by
nporarily storing water and reducing its impact on other surfaces.
iphytes also absorb nutrients from incoming waters and this contributes to a reduction in the loss of minerals to downstream ecosys-
ns.
atomical and morphological characteristics of plants growing at high elevations and low saturation deficits contribute to the in-
ase in transpiration rates. For example, number and size of stomata increase with altitude.
here saturation deficits are high, anatomical and morphological characteristics of plants reduce water loss.
lms develop massive adventitious roots, laden with lenticels, that may contribute to root gas exchange in anaerobic soils.
rface and adventitious roots increase dramatically with increasing water logging of soils.
es maintain epiphyte-laden old leaves for long time periods in spite of the low P/R ratio of these leaves. It appears that their role in
neral cycling and nutrient conservation has more selective advantages than their role as net organic matter producers.
rests have extensive root mats that are essentially mineral-tight.
nts flower for longer periods in the wetter sites and depend on insects and birds for pollination.

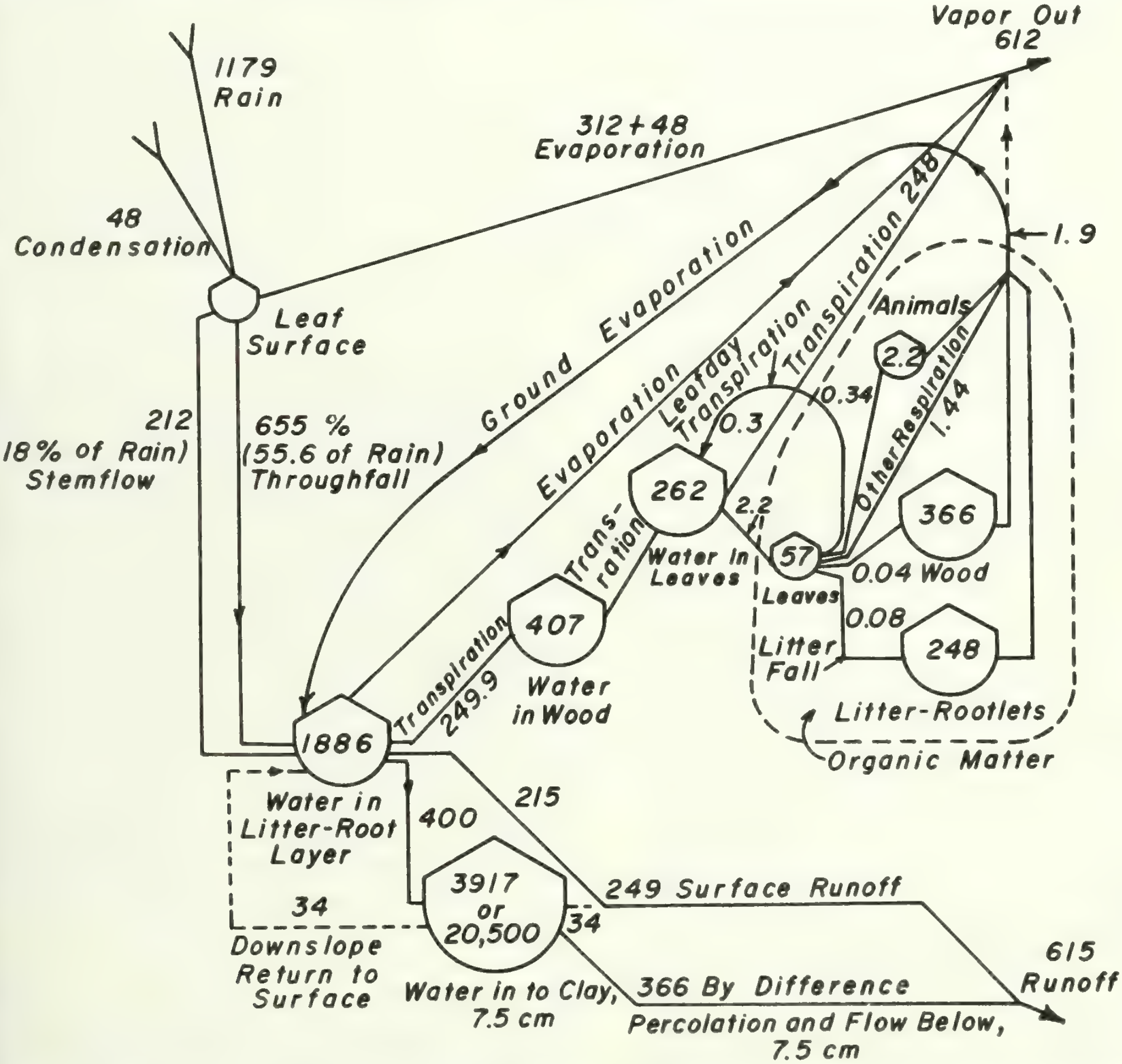

Figure 9.—*Hydrogen budget in the tabonuco forest at El Verde, Luquillo Experimental Forest. Storages are in g/m2 and flows in g/m2.day (Odum et al. 1970).*

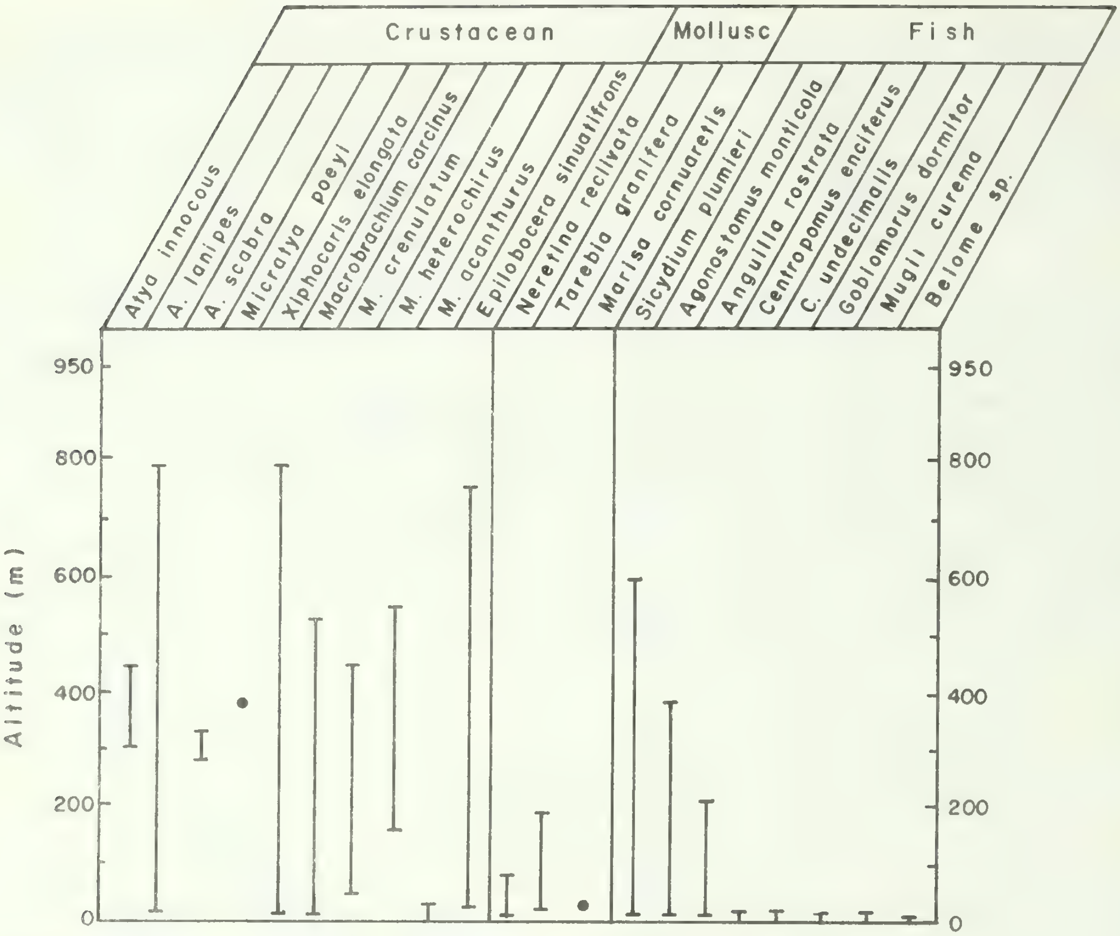

Figure 10.—*Altitudinal distribution of the fauna of the Espiritu Santo River (Bhajan et al. 1980).*

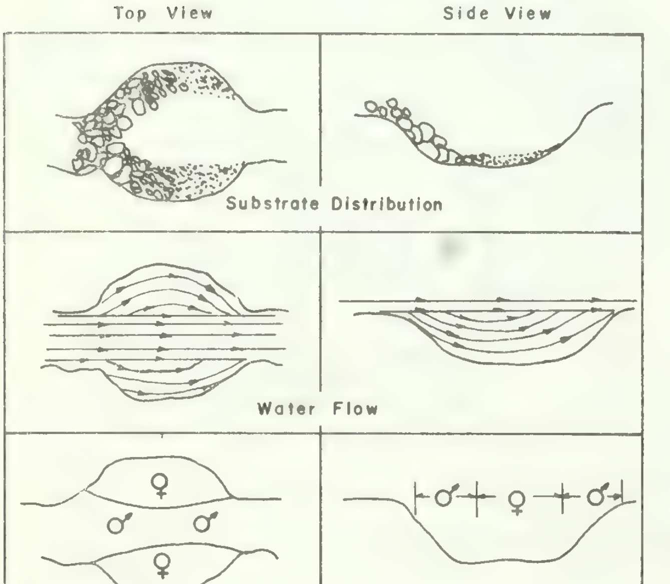

Figure 11.—*Patterns of water flow and substrate distribution in a typical pool in the Espiritu Santo River and their relationship to habitat selection by Atya lanipes (Villamil and Clements 1976).*

karlschmidti uses fast moving streams for its habitat and its food supply (32.4 percent aquatic based), and *E. unicolor* lives in saturated soils at high elevations.

Many species downstream from LEF, including marine, estuarine, and wetland species (table 12), depend on the forest for their survival. Forest evapotranspiration regulates runoff which in turn regulates the salinity of mangrove soils and estuarine waters. The primary production of the coastal complex is a function of salinity, increasing as the salinity decreases with greater runoff (Carter et al. 1973). Corujo Flores (1980) found 60 fish species belonging to 30 families in the Espiritu Santo River estuary alone, their spatial distribution regulated by water salinity. A significant portion of these organisms have commercial value (Erdman 1972; Canals 1979b). Four aspects of water flow are important to downstream ecosystems: water quantity, seasonality of flow, flow variability, and water quality.

Water Quantity

Fast water flows are required to maintain populations of certain aquatic organisms preferring those habitats (Villamil and Clements 1976). Some exam-

Table 12.—*Aquatic fauna of the Luquillo Experimental Forest (Brown et al. 1983)*

Classification	Spanish name
Phylum Chordata	
Class Osteichthyes	
Family Gobiidae	
Scicydium plumieri	chupa piedra
Phylum Arthropoda	
Class Crustacea	
Order Decapoda	
Family Atyidae	
Atya scabra	
A. lanipes	chájara
A. innocous	
Xiphocaris elongata	salpiche
Family Potamonidae	
Epilobocera sinuatifrons	buraquena
Family Palaemonidae	
Macrobrachium carcinus	
M. heterochirus	
M. crenulatum	
M. acanthurus	
Phyllum Insecta	
Order Diptera	
Order Trichoptera	
Order Ephemeroptera	
Order Hydracarina	
Order Odonata	
Phylum Mollusca	
Family Neritidae	
Neritina reclivata	
Family Thiaridae	
Tarebia granifera	
Family Philidae	
Marisa cornuarietis	

les are the shrimp *A. lanipes, A. innocous, and A. cabra* which predominate in fast flow sectors of mon-ane streams. Substrate, along with water flow, are he critical factors that regulate the abundance and roduction of aquatic fauna. However, the substrate f a stream bed is itself a function of the water flow vailable to scour, transport, or deposit materials. herefore, the seasonal distribution and quantity of ater flow are the dominant factors to the mainte-ance of a diverse riverine aquatic fauna. Water flow lso transports larvae to the estuary and food to filter-eding organisms. Many aquatic organisms time heir reproduction to periods of torrential flows which gulate estuarine salinity. Migrations of estuarine ganisms in turn are triggered by changes in salinity Corujo Flores 1980).

easonality of Flow

Seasonality of flow provides a measure of pre-ctability in the signals that trigger reproduction d migration of organisms in the aquatic environ-ent. The periodicity of these events ranges from sea-nal change in base flow (Fig. 7) to occasional phe-mena, such as higher than average annual flows due to offshore storms (Fig. 4). In the south coast of Puerto Rico, rains with frequencies of less than 1 in 50 yr triggered a massive reproduction of *Peltophyrne lemur*, a species thought extinct in that area (Canals and Moreno 1985).

Flow Variability

Although the importance of flow variability to aquatic organisms has not been researched in the LEF, knowledge from other regions suggests this to be a critical factor in their survival (Covich, personal communication, December, 1985). Variability in the stream and accessibility of alternative foods, rather than variability in leaf input or temperature regulate the rate and degree of leaf processing by stream invertebrates (Covich 1985a and b). During very low stream flow the leaching of secondary compounds from leaves causes mortality in stream shrimp and affects their role as detritivores (Covich 1985a and b). For example, leaf leachates caused differences in mortality of *X. elongata* and *A. lanipes* in laboratory and field tests (Covich 1985b). Seven of 12 tree species caused 40–100 percent mortality in *Xiphocaris* while 2 caused high mortality in *Atya*. Low water flows reduce available dissolved oxygen and increase concentrations of toxic elements in stream pools causing reduction, and in some cases elimination of some species of crustaceans and other arthropods in first and second order streams that drain closed canopy forests. High water flows become critical for the reestablishment of optimal habitat conditions and aid the recolonization by invertebrates. Variability in flows presumably prevents the development of prolonged extreme conditions that could be deleterious to organisms. The data on flow rates of LEF streams amply demonstrate the high rate of variability that typifies the streams and rivers of the forest (table 5; figs. 4, 5, 6, and 7).

Water Quality

Salinity is known to trigger larval development of shrimp species in the LEF (Villamil and Clements 1976). Filter-feeders depend on water quality to obtain food and to minimize stress associated with high sediment concentrations. Low chemical oxygen demands contribute to higher dissolved oxygen conditions, which in turn are required to maintain the metabolism of aquatic organisms. Deterioration of water quality is usually associated with drastic reductions in the diversity and productivity of aquatic fauna in Caribbean islands (Harrison and Rankin 1976). In fact, the condition of macroinvertebrate populations can be indicative of the effects of forest management activities on the water quality of rivers (Munther 1985).

CONCLUSION

Water is clearly the driving force of the forests of the LEF. The influence of water over the ecosystems of the LEF is transcendental. Forests consume about half of the annual rainfall, transform water quality, and influence ecosystems in the lowland and coastal areas. A large suite of aquatic organisms take advantage of the variable runoff from the LEF and move up and downstream using estuaries as reproductive nurseries and the oceans or upper watersheds for the adult stages of the life cycles. In the process, these organisms transport materials in both directions, influence processes in the forest and the ocean, and contribute to an intricate food web that yields considerable economic, social, cultural, ecological, and aesthetic value to humans. It behooves water and ecosystem managers to protect the hydrologic flows that make all this traffic and biotic activity possible. Researchers have the complex job of understanding these phenomena so that they can be managed wisely.

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Water dynamics, water balance, and water requirements of the ecosystems and aquatic organisms of the Luquillo Experimental Forest (aka Caribbean National Forest) are reviewed. Objective is to draw attention to research needs and to highlight importance of freshwater allocations to natural ecosystems.

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A Guide to the Insect Borers, Pruners, and Girdlers of Pecan and Hickory

J. D. Solomon and J. A. Payne

SUMMARY

Many insect borers, pruners, and girdlers attack, damage, and kill pecan and hickory trees. By using the information contained in this publication, resource managers, landowners, and other interested people should be better able to identify and manage these pests. Yellow-bellied sapsuckers are also discussed because damage caused by these birds is often confused with that of insect borers. Class, order, and family names of these pests are listed in the Appendix as additional information for the reader.

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A Guide to the Insect Borers, Pruners, and Girdlers of Pecan and Hickory

J. D. Solomon and J. A. Payne

INTRODUCTION

Pecan, *Carya illinoensis* (Wangenh.) K. Koch, and at least 10 species of hickory, *Carya* spp., are native to the Eastern United States. Eight of these are economically important when grown for timber production, commercial nut production, ornamental purposes, and wildlife food. Pecan is best known for its nutritious nuts, which are produced in quantities that make them a major economic commodity, but is also a prized species for use in fine furniture and paneling (Kennedy and others 1981). During recent years, it has been commonly called the "black walnut of the South," and interest in commercial plantings is growing because of its high stumpage value (Adams and Thielges 1976-77). The hickories have long been known for their use in the manufacture of handle stock, sporting goods, and some furniture.

Insect borers, pruners, and girdlers are injurious pests of pecan and hickory. Although most of these pests have a wide distribution, they seldom threaten trees over large areas. Damaging populations typically occur on a local basis, such as a nursery, individual nut-producing grove, forest stand, young timber plantation, or ornamental trees in a neighborhood or small geographic locality. Much has been written on the insect pests affecting the nuts and foliage of pecan, but little has been published on the insect borers affecting the tree itself. The cryptic habits of the insect borers have hampered efforts to document this group of pests. Known information is widely scattered and found in older literature, much of which is not generally available to those who need to use it.

The terminals, branches, trunks, and roots of trees of all sizes are vulnerable to borers. Natural regeneration is sometimes heavily infested by girdlers and pruners. Nurseries and young plantings located close to heavily infested stands or woodlots are most likely to be damaged. Loss of terminals and main stems in young timber plantations adversely affects tree form. Pruners and girdlers can drastically reduce the number of nut-bearing branches and subsequent nut crop of nut-producing trees. Girdled branches can create cleanup problems on residential properties. Young transplanted trees are particularly susceptible to borers and often need protection. Borer holes and associated stain and decay cause defects in the wood that reduce its value for lumber, veneer, handle stock, and other products. Wormholes and bark scars also adversely affect the aesthetic beauty of shade and ornamental trees. Borers sometimes invade the cambium and callus around new grafts and prevent union of scion and stock; recently top-worked trees have suffered serious damage in the past. Stressed trees are particularly susceptible to bark beetles and pin-hole borers. Bark beetles have caused widespread mortality of hickory during extended periods of drought. Yellow-bellied sapsuckers are included in this guide because the holes they peck in the bark are often confused with those caused by insect borers.

Impact from pests can be minimized through good management. Cultural practices that maintain and promote tree vigor are of utmost importance. New plantings should be on good sites, preferably away from heavily infested stands, woodlots, or old, deteriorating orchards. Adequate space, water, and nutrients should be provided. Efforts should be made to keep injuries such as cuts, bruises, and broken limbs resulting from cultivation, mowing, thinning, and harvesting equipment to a minimum. Injuries that do occur should be promptly treated to speed the healing process. Practices such a "pick-up and destroy" and "prune-out and destroy" can help to reduce damage by girdlers and pruners, especially when practiced on an area or neighborhood basis. When possible, practices should be adopted that favor natural controls such as predators, parasites, and insect pathogens. Chemical control may occasionally be needed.

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This publication should aid forest managers of timber resources, farm managers of nut producing groves, extension and pest control personnel, and homeowners to identify, manage, and control the major insect borer, pruner, and girdler pests of pecan and hickory. Descriptions and illustrations of the pests and their damage—including galleries, frass, size and portion of tree infested, and tree condition—are presented to aid in identification. Information on biology and control are given to help in predicting damage, managing populations, and making control decisions. Specific chemical controls are not given in this publication. For the latest information on pesticides contact your State Forester, Extension Agent, or the nearest office of State and Private Forestry, USDA Forest Service.

PECAN CARPENTERWORM

Cossula magnifica (Strecker)

Importance.—The pecan carpenterworm, *Cossula magnifica* (Strecker), is primarily a pest of pecan, but is also found in the hickories and reportedly some oaks throughout the Southern United States and Mexico (Baker 1972, Matz 1918, Moznette and others 1931). It attacks the branches and trunks of trees of all sizes, but shows a preference for trees 8 to 31 cm d.b.h. Small branches may break or dieback at the tunneled sites. Although very few trees break or die from carpenterworm attack, heavy repeated attacks may structurally weaken the tree, reduce its vigor, and provide entryways for decay fungi and other pathogens. The value of sawlogs and lumber from infested trees is markedly reduced because wormholes will cause the wood to be degraded. Although populations may be heavy locally, widely scattered infestations and sporadic appearance minimize the overall economic impact of the pecan carpenterworm.

Description.—The adult is a grayish moth mottled with brown and black blotches (fig. 1A) (Moznette and others 1931, Baker 1972, Gill 1924). The forewings are mottled with small brown patches, and each has a large brownish area at the distal end; the hindwings are uniformly darker without distinct markings. The wingspan ranges from 37 to 44 mm. The larva is pinkish in color and naked or only sparsely covered with short fine hairs that arise from the numerous tubercles (fig. 1B). The head, cervical shield, and anal plate are shiny dark brown. The full-grown larva may reach 37 mm in length. The pupa is brown and has a sharp projection on its head that is used to help force its way through the pupal cell and along the larval burrow to the exit hole.

Evidence of Infestation.—The earliest signs of attack are entrance holes, sap-stained bark, and small quantities of moist frass on the small branches during

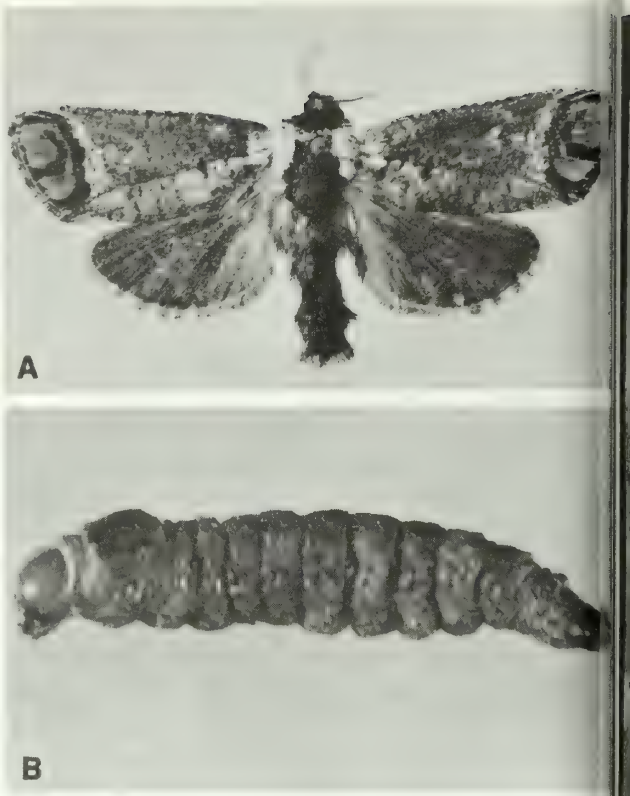
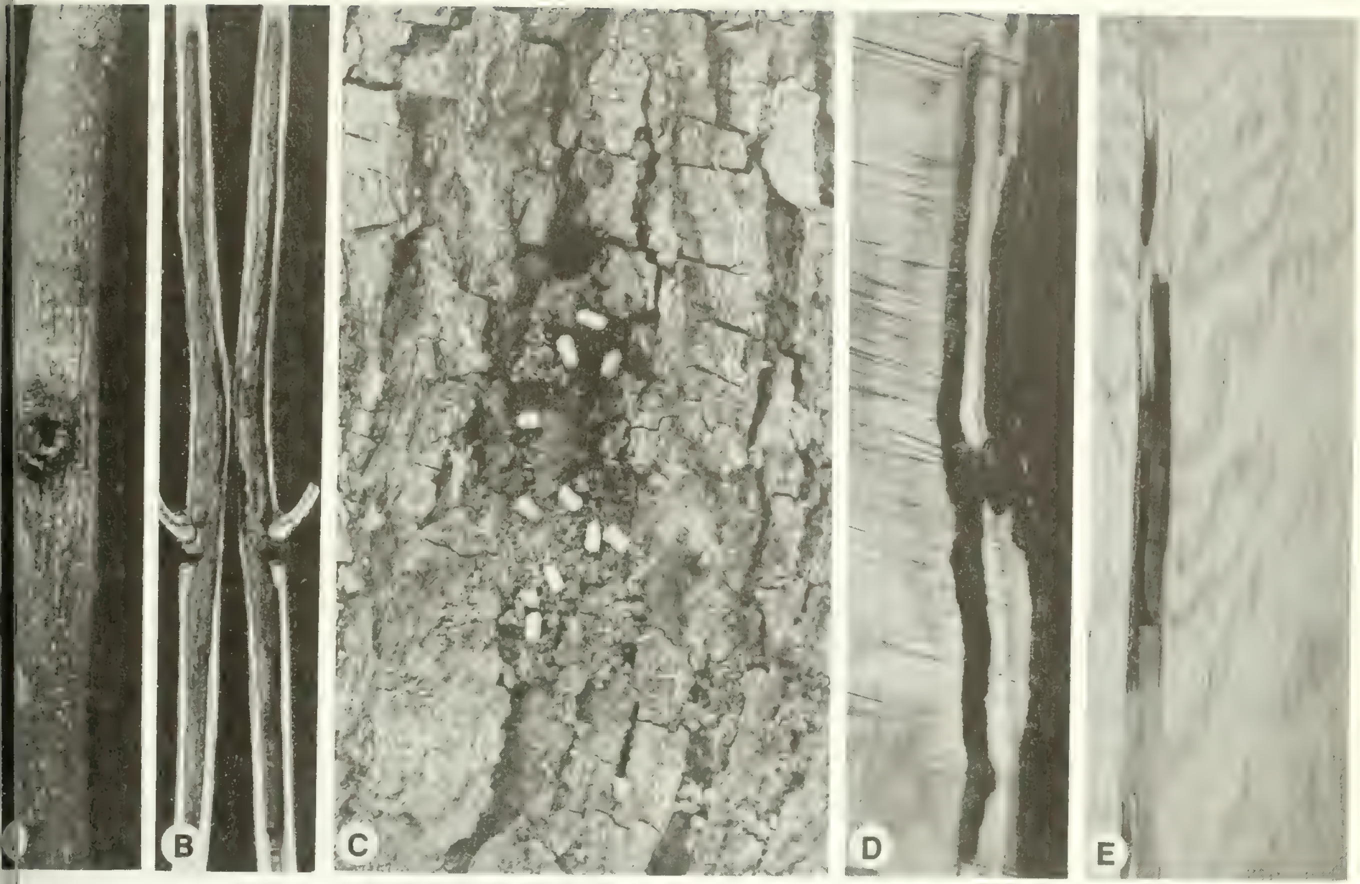


Figure 1.—*Life stages of* Cossula magnifica: *(A) adult mot*
mature larva.

summer and early fall (fig. 2A). Dissecting th
fested branch will reveal the larval tunnel (fig.
However, these signs are often overlooked becaus
infested branches may be high above the ground,
the frass becomes scattered as it falls to the groun
becomes easier to recognize the attacks when the
vae later bore into the trunk during the aut
(Moznette and others 1931, Turner and others 1
Although attacks may occur at any point on
trunk, they are usually concentrated around the
part of the trunk from groundline up to about 1.
Attacks in the trunk are characterized by a s
circular entrance hole about 6 mm in diameter
sap-stained bark below the entrance and a few e
ment pellets and fine frass in bark crevices (fig.
Pellet-like frass often accumulates in piles on
ground around the base of infested trees. Entr
holes are enlarged to about 9 mm just prior to p
tion. Brown pupal skins may be found protru
from entrance holes during emergence in May
June. Entrances to galleries heal over leaving
formly round or oval bark scars for several yea
evidence of previous attacks.

Biology.—Eggs are deposited on the bark of s
branches in the tops of trees after emergence and
ing of the adult moths from late April through
(Baker 1972, Moznette and others 1931, Gill 1
The newly hatched larvae first attack small twig



ure 2.—*Injury by larvae of* Cossula magnifica *in pecan: (A) entrance hole with sap-stained bark in small branch; (B) small branch dissected to expose gallery; (C) entrance hole, frass, and stained bark in large trunk; (D) completed gallery in wood of large trunk; (E) wormhole and stain defects in lumber.*

nches and tunnel out the pithy center (fig. 2B). en the larva becomes too large for the small twig, rawls out and enters a large branch. Entrances in gs and small branches are usually made adjacent buds, leaf petioles, or small secondary branches. larva may tunnel up to 10 cm in both directions n the entrance hole, leaving only shells of small nches 10 to 13 mm in diameter. By early fall the vae vacate their branch galleries, crawl downward the bark, and bore into the trunk and large nches. Larvae attacking the trunk usually initiate leries in bark crevices and tunnel horizontally or iquely upward for 13 to 32 mm, then vertically for ther 6 to 13 cm (fig. 2D). Many larvae also tunnel nward from the point of entrance another 5 to cm. The cross-section of the vertical portion of the lery is usually round, and about 6 mm in diameter. wormholes and associated stain and decay show as defects in the lumber (fig. 2E). The insect overters as a larva within the gallery. The following il or May the mature larva enlarges the entrance e and then encloses itself and pupates in the upper of the gallery behind a very peculiar but charac- stic barrier or network of threadlike material. The rp projection on the head end of the pupa enables the pupa to move through the barrier and down the tunnel to the entrance hole for emergence. Entrances to vacated galleries heal over, leaving uniformly round or oval bark scars in the bark (fig. 3). Although little is known about the life history, there appears to be one generation per year.

Control.—Although reported to occur throughout the South from North Carolina to Florida and west to Texas, infestations are generally widely scattered (Boethel and others 1980). Trees planted as ornamentals or in orchards, groves, or other open-grown situations are generally more heavily infested than those growing in well-stocked forest stands. Care should be exercised so that new plantings are not established adjacent to old orchards or stands heavily infested with carpenterworms. Keeping the trees in vigorous condition and free of disease cankers and mechanical injuries will help to prevent infestation. Two tachinid parasites, *Phorocera comstocki* Williston (Leiby 1925) and *P. signata* Aldrich and Webber have been reared, but little is known of their effect on carpenterworm populations. Small numbers of borers can be controlled by injecting a fumigant into the gallery and then using clay or putty to plug the entrance hole. Insecticides used periodically in groves to control nut

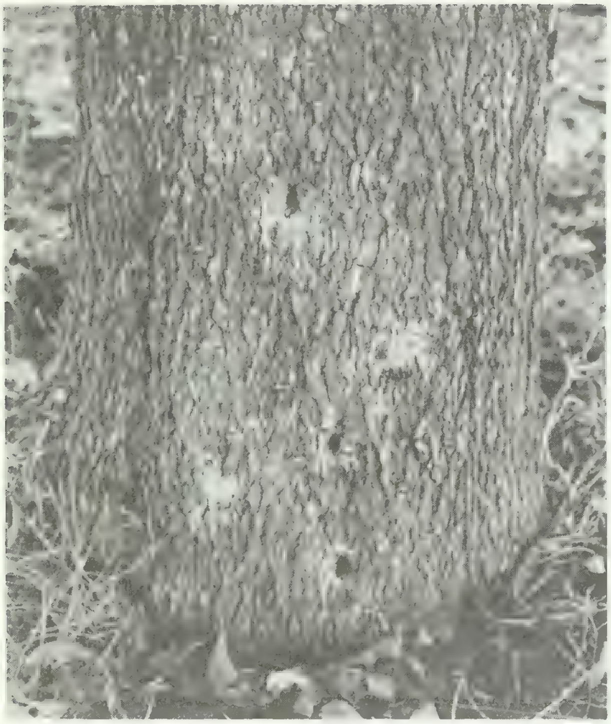


Figure 3.—*Round, oval scars in bark provide evidence of previous attack by* Cossula magnifica.

and foliar insects provide some, but not complete, control of carpenterworms. Chemical control specifically for pecan carpenterworm is seldom justified (Boethel and others 1980).

DOGWOOD BORER
Synanthedon scitula (Harris)

Importance.—Although the dogwood borer, *Synanthedon scitula* (Harris), is perhaps best known for its economic damage to the flowering dogwood for which it is named, it sometimes causes serious damage to pecan (Herrick 1904, Moznette and others 1931). It has also been found attacking hickory, oak, and many other species. It is known from southeastern Canada southward over the Eastern United States west to Texas. Damage results from the larvae feeding just beneath the outer bark in the phloem and cambium. Individual branches and even young trees may be completely girdled and killed, but most often the stem is only partially girdled or patches of bark killed. Attacks may occur at any point on the trunk and branches of trees of all sizes. Trees that are wounded, diseased, or in poor vigor are most susceptible to attack. It often attacks grafted and budded trees, destroying much of the cambium and callus tissue and preventing the union of scion and stock. Topworked trees have suffered serious damage in the past.

Description—The adult is a delicate bluish-bl clearwing moth with yellow markings on the thor yellow-banded legs, and yellow stripes on segme two and four of the abdomen (fig. 4A) (Herrick 19 Pless and Stanley 1967). Wings are transparent w bluish-black margins and have a wingspan of 14 20 mm. Eggs are pale yellow to brown, elliptical shape, and about 0.5 mm long and 0.4 mm in dia ter. Larvae are off-white to cream colored w reddish-brown heads, and range in size from less th 1 mm when newly hatched to 14 mm when mat (fig. 4B). The prothoracic shield has two do yellowish-brown spots. The pupa is brown and mains inside a cocoon until time for adult emerge

Evidence of Infestation.—The most easily rec nized early sign of attack is the presence of fine fr that has been extruded from the tunnels thro small openings in bark crevices (Herrick 1904, Un hill 1935). By cutting away the outer bark, la tunnels and feeding larvae can be exposed (fig. 4 When inspecting trees for damage, it is importan examine the lower trunk of young trees, especi around and just above the groundline. Trees woun

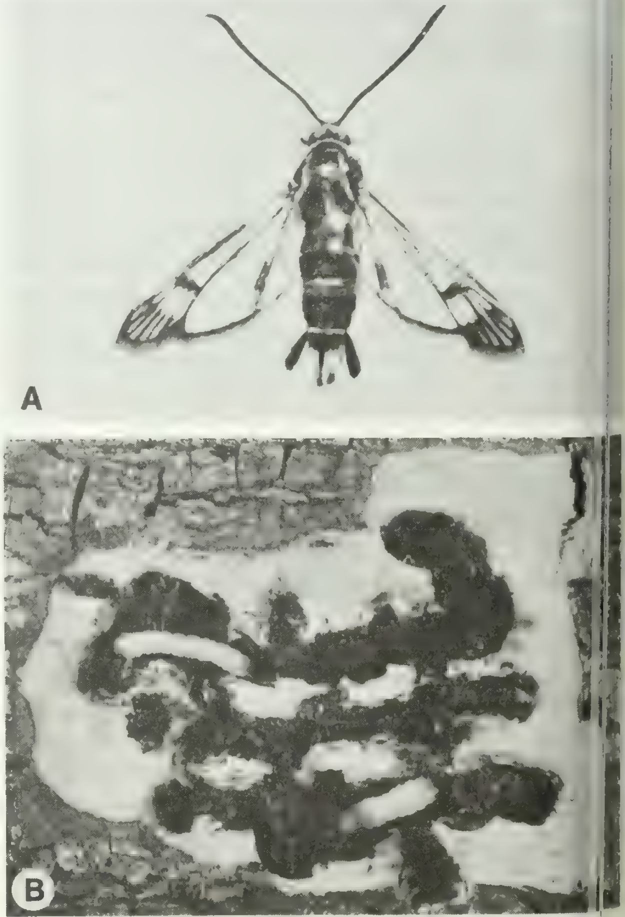
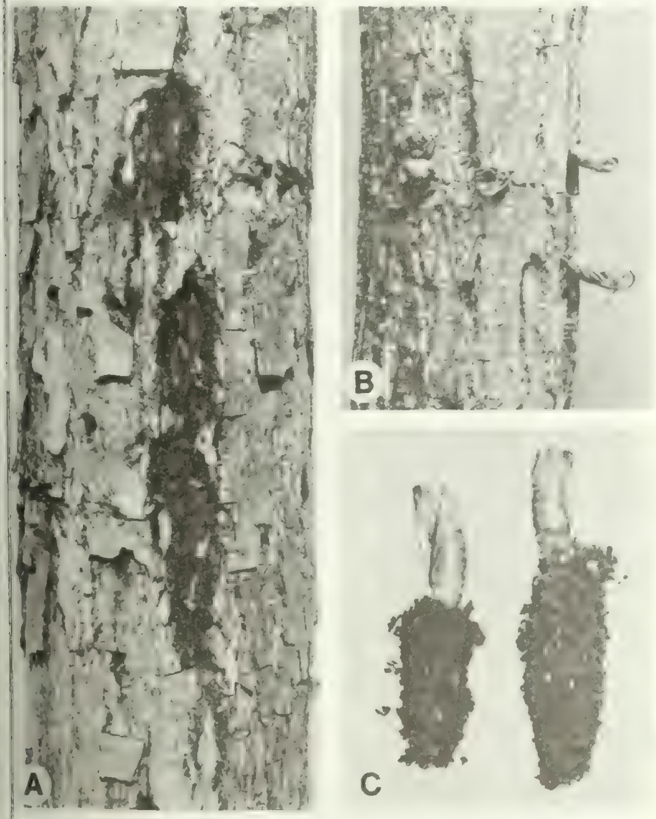


Figure 4.—*Life stages and tunnels of* Synanthedon scit *in pecan: (A) adult clearwing moth; (B) bark remo exposing the larvae and burrows.*

diseased, or in poor vigor are most susceptible to attack and should be inspected frequently. After trees have been infested for a year or so, the dead bark over the borer tunnels begins to loosen and break away, sometimes exposing the wood beneath (fig. 5A). Trees that are badly infested may have an unhealthy appearance, exhibit dieback of branches in parts of the crown, and send out sprouts from near the groundline. Mortality occurs if trees are completely girdled. Graft failures should be inspected closely for evidence of infestation. Frass around fresh wounds and points of grafting and budding can mean the beginning of an infestation. Small brown pupal skins may be found protruding from the bark from April through October (fig. 5B). Exposure of infested sites by prying the bark loose frequently reveals one to a dozen or more larvae of various sizes feeding close together in localized tunnels.

Biology—Adults emerge from April to October with the greatest number appearing in the early part of the year (Pierce and Nickels 1941, Pless and Stanley 1967). Eggs may be deposited on the bark anywhere along the trunk or branches, although most are placed close to wounds, on or adjacent to frass, near openings produced by other borers, and around grafts or buds. The eggs hatch in 8 to 9 days. Newly hatched larvae are small, fragile, and very sensitive to humidity; many die from dessication before locating a suitable niche to begin boring. The newly hatched larvae are able to move short distances and usually seek wounds, fresh grafts, and tunnels of other borers to become established, although a few are able to successfully establish burrows at uninjured sites. Larvae make irregularly shaped tunnels or burrows that spiral upward in the bark and cambium. Although the sapwood may be etched, no burrows are made into the sapwood. Larvae of various sizes overwinter in their burrows and are able to withstand a wide range of temperatures. The following spring the immature larvae continue feeding, while the mature ones pupate. The mature larva usually prepares a cocoon of frass and silken threads in the burrow beneath the outer bark for pupation (fig. 5C). Pupae within cocoons are rarely found in the leaves and trash around the base of the tree. The pupal stage lasts 8 to 12 days. There is one generation per year, with some evidence of a second generation in its southern range.



igure 5.—*Evidence of attack by* Synanthedon scitula *in pecan: (A) active attack on trunk of young tree; (B) pupal skins in bark are positive signs of infestation; (C) dark-brown frass-covered cocoons just under the bark with protruding pupal skins.*

Control.—Except under conditions favorable for the borers, natural enemies usually keep infestations in check (Pless and Stanley 1967, Underhill 1935). Parasites that have been recovered are four braconids, *Apanteles sesiae* Viereck, *Agathis buttricki* Viereck, *Microbracon sanninoidae* Gahan, *M. mellitor* Say, two ichneumonids, *Phaeogenes ater* Cress., *Scambus (Itoplectis) conquisitor* Say, and one eulophid, *Hyssopus sanninoidae* Gir. In some cases, up to 50 percent of the larvae are parasitized. A disease caused by the fungus *Cordyceps* sp. has been found but is not prevalent. Woodpeckers excavate a small number of larvae. Adhering to recommended cultural practices for keeping trees vigorous and free of bark injuries is important in preventing serious damage due to dogwood borers. Direct control is seldom needed in natural stands but is sometimes needed in groves, nurseries, and ornamental trees (Pierce and Nickels 1941).

AMERICAN PLUM BORER
Euzophera semifuneralis (Walker)

Importance.—The American plum borer, *Euzophera semifuneralis* (Walker), a pest of pecan and hickory, has a wide host range, being especially troublesome to fruit trees (Blakeslee 1915, Pierce and Nickels 1941). It is widely distributed throughout the United States and is also found in Canada, Mexico, and Columbia, South America (Heinrich 1956, Forbes 1890). It is primarily a pest of trees in poor vigor, usually attacking trees that have been mechanically wounded or infected by canker-type fungous diseases. The larvae rarely succeed in establishing themselves on healthy, uninjured trees. Damage results from the larvae feeding in the cambial area, sometimes girdling and killing small trees. It may also be found feeding on the callus tissue of recently grafted or budded trees. Graft failures are sometimes attributed to this borer.

Description.—The adult has a light-gray body with grayish-brown forewings that have a broad, wavy band of black and brown markings (fig. 6A) (Blakeslee 1915, Heinrich 1956, Forbes 1890). The hindwings are smokey gray with a distinct black margin. The wingspan ranges from 17 to 25 mm. Eggs vary from dull white when deposited to pink or brown as incubation progresses. Each egg is oval and measures about 0.6 mm long and 0.4 mm in diameter. The larva is white when newly hatched but the color varies from dull white to pinkish or reddish brown as it develops (fig. 6B). The head is dark brown and the cervical shield is pale yellow with black markings on the sides. Full-grown larvae range from 16 to 28 mm and average about 25 mm in length. The pupa is brownish black and is found inside a white silken cocoon.

Evidence of Infestation.—The most obvious sign of infestation is an accumulation of dark-brown or black frass adhering to the bark at the site of attack (Blakeslee 1915, Pierce and Nickels 1941). The frass typically is made up almost entirely of excrement p lets stuck or adhering loosely together by sap exuda and silken threads. Attacks are limited almost e tirely to trees with mechanical wounds, frost damag sun scalds, disease cankers, pruning wounds, and r cent grafts and buds (fig. 7A). Patches of dead or d eased cambium or partially girdled stems are favor sites for invasion. Larvae, larval burrows that exte into the living tissue, and accumulations of frass c be exposed by lifting pieces of dead bark. The presen of one or more loosely woven cocoons of white silk threads under the bark is very characteristic of t American plum borer (fig. 7B). The white silken coons distinguish this borer from the dogwood bor which has dark-brown or black cocoons usually e tirely covered with frass. Attacks may be found trees and branches of all sizes, but they are most co monly found on the lower trunk just above t groundline.

Biology.—The insect overwinters as a larva in white silken cocoon under loose bark near the trance to its feeding burrows (Blakeslee 1915, Pie and Nickels 1941). Pupation occurs within the coco during March and early April and lasts 20 to 30 da Adults emerge during April and May. The fema mate and begin ovipositing 1 to 3 days after em

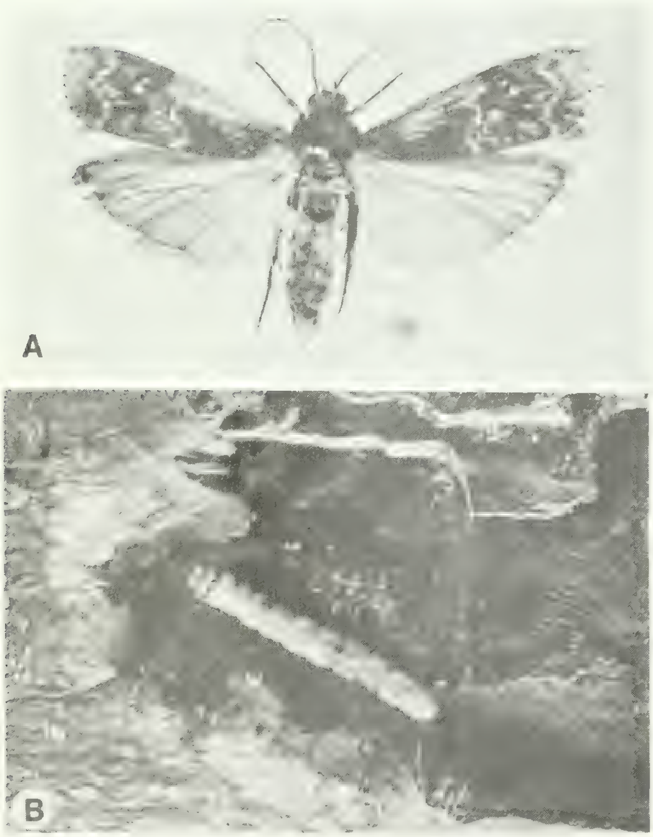


Figure 6.—*Life stages of* Euzophera semifuneralis: *(A) adult moth; (B) nearly grown larva.*

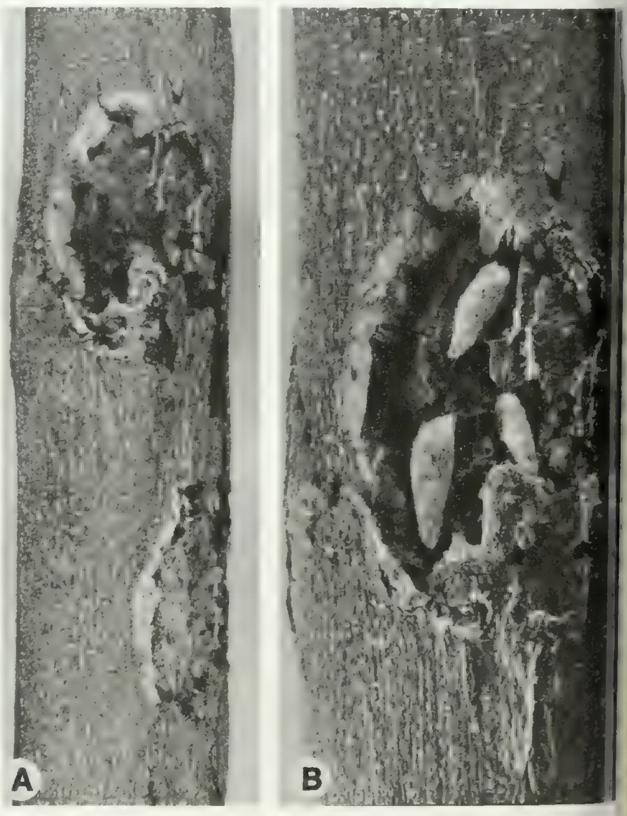


Figure 7.—*Evidence of infestation by* Euzophera semifuneral *pecan: (A) bark removed to expose tunneling in (B) closeup of white silken cocoons in mined cavity*

nce and deposit eggs for 1 to 4 days. Females deposit fm 12 to 74 eggs singly on twigs or in small groups i cracks and crevices of the bark of suitable host tes. The eggs hatch in 8 to 14 days and the young lrvae seek wounds, cankers, and other suitable sites t begin feeding. The larval development period is 4 to weeks. The mature larvae construct loosely woven coons of white silken threads under the bark for pation. The pupation period for summer broods lsts 10 to 18 days, about half the time required for sring pupation. There are two or more generations r year. Larvae may be found almost continuously, idicating considerable overlapping of broods.

Control.—Because the insect is largely incapable of eablishing itself in healthy, vigorous, uninjured tes, damage is unlikely except when trees suffer fm frost injury, sun scald, mechanical wounds, or cnker-type fungous diseases (Blakeslee 1915, Kelsey ad Stearnes 1960, Pierce and Nickels 1941). Therefe, good cultural practices that prevent such injuries hlp to minimize damage from the American plum brer. Five ichneumonid parasites, *Mesostenus thoricus* (Cress.), *M. gracilis* Cress., *Itoplectis marginat* (Prov.), *Pimpla* sp., and *Idechthis* sp., help to suppss infestations. An unidentified threadworm prasite has also been reared. Predators include lrvae of the ostomid, *Tenebrioides corlicalis* lsheimer, ants, and woodpeckers. Chemical control ipossible but seldom needed.

ACROBASIS SHOOT BORERS

Acrobasis spp.

mportance.—The acrobasis shoot borers are pests o pecan and hickory as well as black walnut and bternut from Ontario and Quebec in southeastern Cnada southward to Florida and west to Texas in the ited States (Baker 1972, Neunzig 1972). Some of th more important species include *Acrobasis nxvorella* Neunzig, *A. juglandis* (LeBaron), *A. caryivella* Ragonot, and *A. demotella* Grote. The acroba shoot borers are perhaps best known for their dama to foliage and nuts, although they often act as sot borers during spring when growth begins (yne and others 1979, Neunzig 1972). Boring and tneling by the shoot borers cause many new tender sots to become stunted, distorted, or die. Seedlings i nurseries can suffer serious damage. Mortality to t terminals of young trees intended for timber prodtion is perhaps the most damaging type of injury (arby 1978). The destruction of terminals causes ruced growth and dichotomous branching, which rults in forks, crooks, and abnormal branching. Reted terminal injury during early growth can avsely affect the tree form that is so important when t goal is production of saw logs for lumber, veneer, a other products.

Description.—The adults are grayish to brownish moths with reddish, black, or white markings on the forewings and a wingspan of 12 to 20 mm (fig. 8A) (Payne and others 1979, Gill 1925, Neunzig 1972). The eggs are oval to elliptical, convex above and flattened below, with a reticular micropattern on the outer surface of the chorion. When first deposited, the eggs are greenish white, but they gradually assume a whitish and then reddish tinge as development progresses. Eggs vary from 0.5 to 0.8 mm in length and 0.25 to 0.36 mm in width. Newly hatched larvae are pale reddish brown and about 0.8 mm long. Mature larvae (fig. 8B) are cylindrical, taper slightly toward each end, and 10 to 19 mm in length. Head and mouthparts are dark yellowish brown; the prothoracic shield is pale brown; and the body is olive green to jade green, usually darker dorsally than ventrally. The newly formed pupa is olive green but gradually changes to light brown.

Evidence of Infestation.—Shoot damage occurs almost entirely during the spring (Martinat and Wilson 1978, Neunzig 1972, Payne and others 1979). The earliest evidence of injury may be holes in the swelling and unfolding buds. The majority of attacks to the shoot occurs after the buds have opened, but before there is much elongating or unfolding of the leaflets. Entrance holes are usually made into the basal part of the shoot just above the terminal leaf scar of the previous season's growth. However, some larvae make entrance holes some distance out on the shoot, usually where the inner base of a petiole joins the shoot (fig. 9A). Small amounts of frass are extruded from the gallery entrance and silked together to make a short loose tube, often forming an extension of the tunnel in all except *A. demotella,* whose larvae do not form a frass tube. The frass tube often becomes prominant as loosening bud scales and additional frass are silked together. Tunnels excavated in the tender shoots by the larvae range from 6 to 45 mm long (fig. 9B). The injury usually causes the terminal parts of the tender shoot to wilt, turn yellow and then brown, and die (fig. 9C). Tunneled shoots sometimes become enlarged, swollen, or gall-like. Injured shoots that survive often become stunted and deformed and lose apical domi-

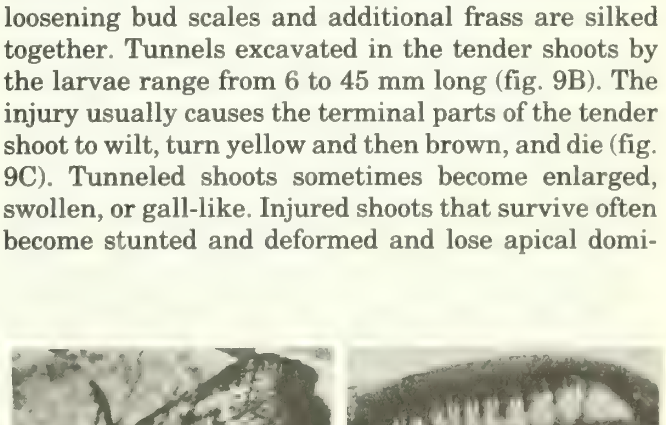


Figure 8.—*Life stages of* Acrobasis *spp.: (A) adult moth; (B) larva in burrow.*

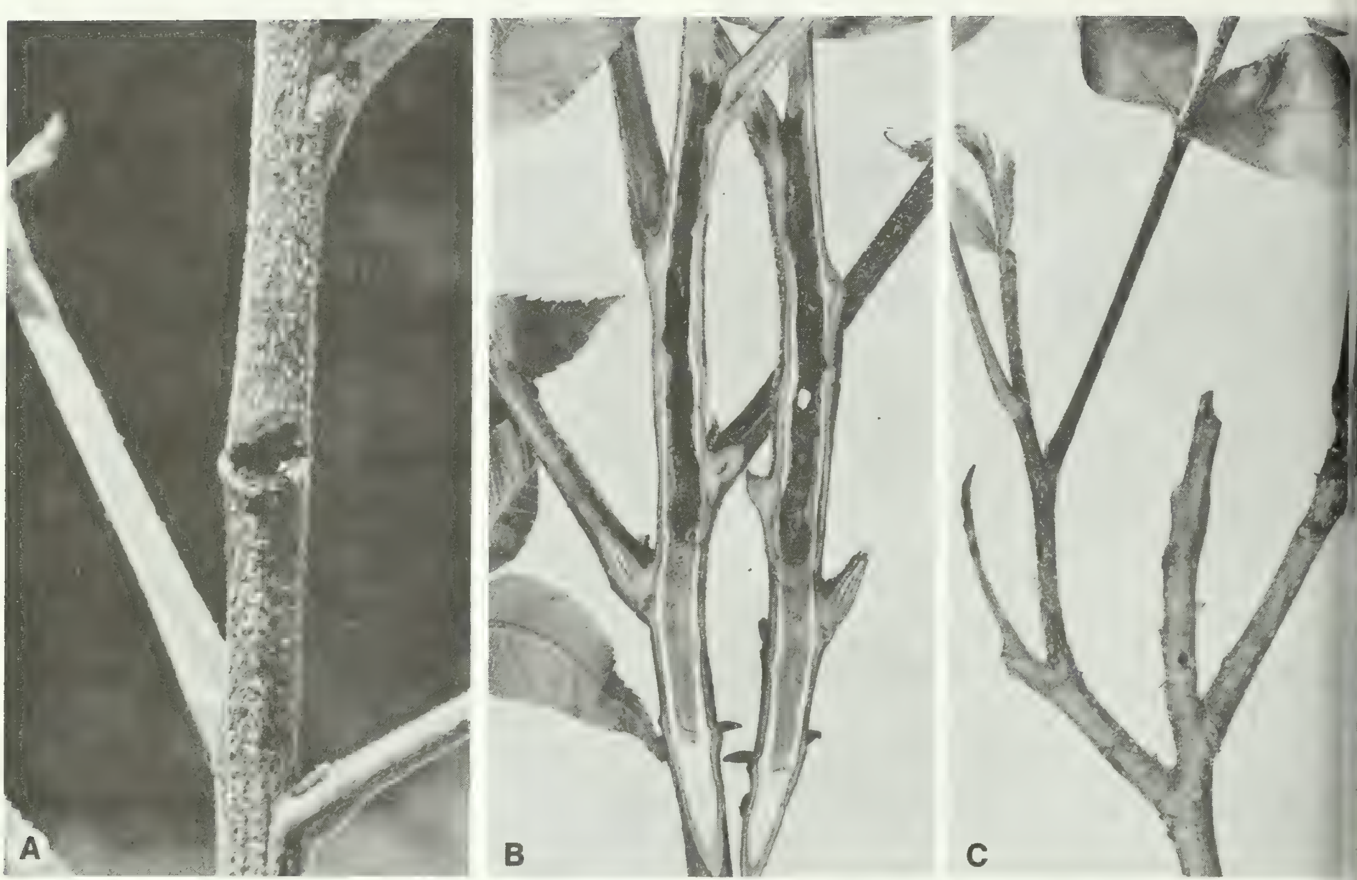


Figure 9.—*Signs of infestation by* Acrobasis *spp. in pecan: (A) entrance hole in terminal shoot; (B) young shoot dissected to expose gall*
(C) shoot terminal killed by larval tunneling.

nance to a lateral shoot. The different species of *Acrobasis* can be partially separated by habits in attacking buds and shoots, site of entrance into the shoot, amount of tunneling, and characteristics of the frass tube and/or silking together of adjacent leaves, petioles, and shoots (Neunzig 1972).

Biology.—The shoot borers overwinter as partially grown larvae in tightly woven cocoons called hibernacula, typically found where a bud joins the stem (Neunzig 1972, Martinat and Wallner 1980, Payne and others 1979). The larvae emerge from the hibernacula in early spring and tunnel into the swelling buds and tender new shoots. When mature, a few larvae pupate within the galleries, but most vacate the tunnels and pupate under barkplates or drop to the ground and burrow into the litter or soil and pupate. The pupal stage lasts 11 to 18 days. Moths emerge and deposit eggs singly or in small groups, usually on nuts near the base of calyx lobes, on or near buds, and on the underside of leaflets. The eggs hatch in about 7 to 10 days. There may be one to four generations per year depending on species and north-south location. In the fall, third instar larvae construct and overwinter in hibernacula on or adjacent to a bud. Only during the spring do the larvae attack the shoots; later broods feed on the nuts and foliage (Payne and others 1979).

Control.—Natural enemies help in keeping the
robasis shoot borers in check. Parasites are probal
the most important group of natural controls; ma
species of parasites have been reported (Neun
1972, Martinat and Wallner 1980, Gill 1925). Wh
new plantings are established, they should be locat
away from existing areas containing *Carya* a
Juglans spp. Corrective pruning during early grow
may be the best alternative to control, especia
when plantings are intended for timber purpo
(McKeague and Simmons 1978). Pruning should
done in May or early June, soon after the curr
season's shoot damage ceases. The pruning technic
should retain the strongest newly developing shoot
the new terminal. Corrective pruning aims to reest
lish apical dominance by one shoot in order to corr
forks that may have resulted from terminal bud
jury, thus improving tree form. Insecticides may
necessary when infestations are heavy (Payne a
others 1979).

HICKORY SHOOT CURCULIO

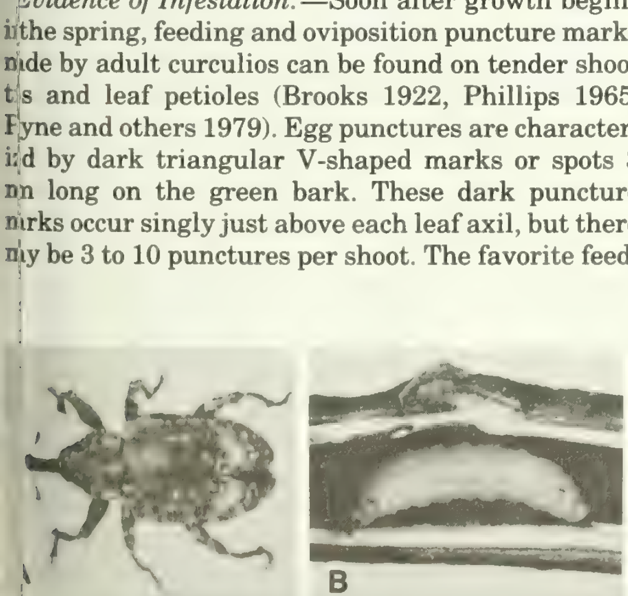
Conotrachelus aratus (Germar)

Importance.—The hickory shoot curculio, *Conot*
chelus aratus (Germar), attacks pecan and hick
throughout the Eastern United States from Mas

usetts south to Florida and west to Texas and Kan- s (Phillips 1964, Schoof 1942, Brooks 1922). Injury sults from both adult and larval feeding. Injury m larvae tunneling within the new shoots and leaf ms is most damaging, resulting in premature fo- ge loss and weakening or death of nut-producing oots. Loss of terminals in young trees intended for nber production can result in forks and abnormal ink development. Heavy damage has occurred in tigs and shoots on young budded trees in nurseries. vere infestations are found most often on unman- ed trees or in groves adjacent to woodlands contain- g native pecan and hickory trees (Payne and others 179). Fifty percent or more of the shoots can become fested. Two other curculio shoot borers, *C. elegans* ay) and *C. tibialis* Brooks, cause injuries similar to *aratus* but are less prevalent.

Description.—The adult is a weevil-type beetle th a short, stout snout that is slightly curved and out one-third the length of the body, or about as g as the head and thorax combined, and has the rnum grooved for reception of the beak (fig. 10A) rooks 1922, Payne and others 1979, Schoof 1942). e color is dull grayish to reddish brown with an listinct broad band of yellowish pubescence behind e middle of the elytra and a narrow line of the same or on each side of the thorax. Adults average about nm long and 2 mm wide. The egg is oval to oblong, amy white, semitransparent, and averages 1.1 mm g and 0.7 mm in diameter. The larva is yellowish ite with a brown head and black jaws and has a ttering of short but noticeable setae (fig. 10B). The va is legless, slightly curved or crescent shaped, d averages about 6.0 mm long and 1.5 mm in di- eter. The pupa is delicate and white but gradually rkens.

vidence of Infestation.—Soon after growth begins the spring, feeding and oviposition puncture marks de by adult curculios can be found on tender shoot s and leaf petioles (Brooks 1922, Phillips 1965, yne and others 1979). Egg punctures are character- d by dark triangular V-shaped marks or spots 3 n long on the green bark. These dark puncture rks occur singly just above each leaf axil, but there y be 3 to 10 punctures per shoot. The favorite feeding place of the larva is in the bulblike swelling at the base of the leaf petiole, but it also mines in the pith of new shoots and leaf stems (fig. 11A). An active larval gallery usually has a small amount of dark frass at the entrance (fig. 11B). Dissection will reveal the crescent-shaped larvae. The burrows or galleries may range from 25 to 51 mm long (fig. 11C). The affected shoot tips and leaves usually become yellowish or brown and wither on the tree or drop away. Shoots that are heavily tunneled often break and drop without turning yellow and withering. Late summer and fall feeding by the newly emerging adults cause feeding puncture wounds along the shoot and leaf petioles, but late season damage is negligible.



ure 10.—*Life stages of* Conotrachelus aratus: *(A) adult weevil; (B) mature larva.*

Biology.—The hickory shoot curculio overwinters in the adult stage in litter, trash, or debris on the ground near host trees (Brooks 1922, Payne and others 1979, Schoof 1942). Adults emerge from hibernation and become active in early spring as buds begin unfolding and shoot growth begins. Feeding begins in late March and April in the south and 2 to 4 weeks later in the northern range. After feeding for a short time, females deposit eggs singly in puncture niches in the tender shoot tips and leaf petioles just above the enlarged petiole base. Eggs hatch in about a week and the larvae begin feeding and tunneling within the tender new growth where they complete their larval development. When fully grown by midsummer, the mature larvae vacate their galleries, drop to the ground beneath the tree, and burrow into the soil to a depth of 12 to 51 mm where they form unlined, earthen cells for pupation. The pupal period lasts for 2 to 3 weeks. The adult curculios emerge from the ground mostly during August and September. Emerging adults are comparatively inactive and feed very little before entering hibernation in the autumn. There is one generation per year.

Control.—Fifty percent or more of the larval population may be destroyed by parasites (Brooks 1922). The three species of parasites identified from the larvae are two tachnids, *Myiophasia globosa* (Townsend) and *Cholomyiae inaequipes* Bigot, and one chloropid, *Chaetochlorops inquilinus* (Coquillett). New plantings should be established, when possible, away from heavily infested woodlots. Sanitation and cultural practices such as clipping, collecting, and destroying infested shoots can reduce populations when only a single or few high-value trees isolated from surrounding host trees are involved. Elimination of trash and debris can also help to eliminate hibernation sites. Chemical control is usually not necessary but occasionally may be needed when many adults are present or when there is a history of damage (Payne and others 1979, Phillips 1965, Brooks 1922). Up to three spray applications, beginning in early spring when unfolding buds have 6 to 25 mm of new growth, may be necessary to control the adults before they lay their eggs.

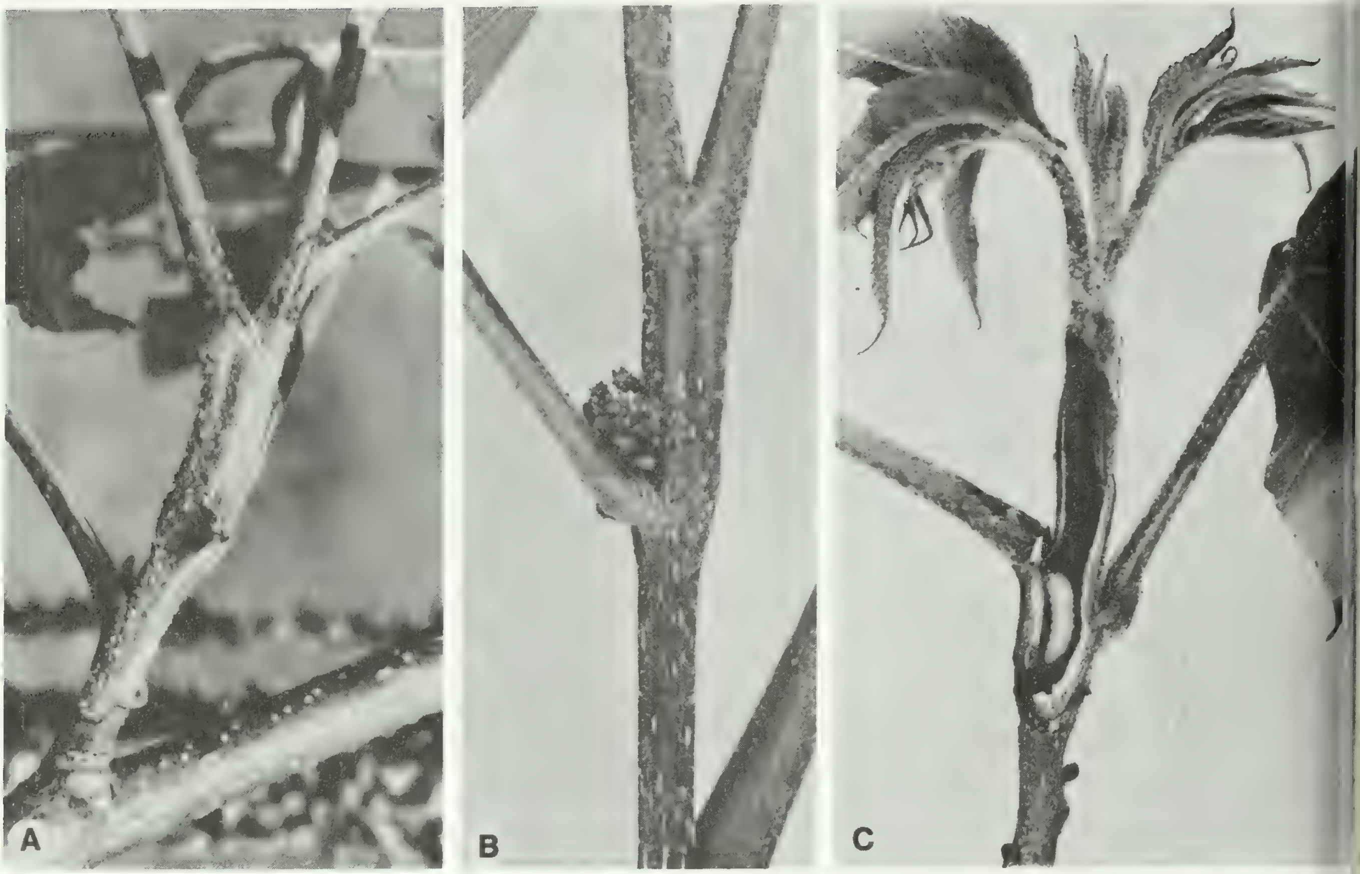


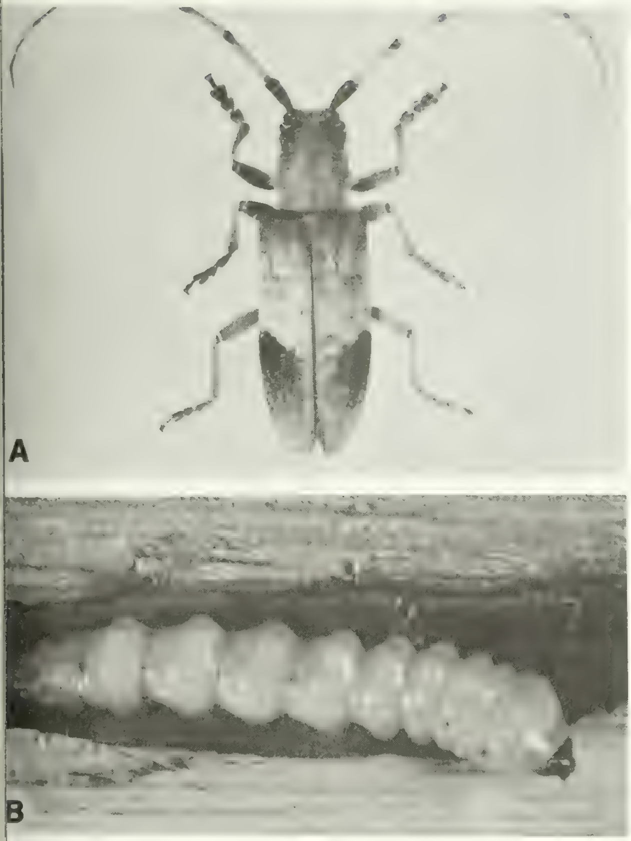
Figure 11.—*Young hickory shoots infested by* Conotrachelus aratus: *(A) swollen shoot with larval entrance hole; (B) dark frass being eje from gallery entrance; (C) terminal dissected to expose gallery and young larva.*

HICKORY BORER
Goes pulcher (Haldeman)

Importance.—The hickory borer, *Goes pulcher* (Haldeman), is found from southern Canada throughout the Eastern United States, and although primarily a pest of the hickories, will occasionally attack pecan (Baker 1972, Beal and others 1952, Solomon 1974). The larvae tunnel in the sapwood and heartwood of young trees 2 to 14 cm in diameter, mostly from groundline up to about 5 m. Attacks in large trees are infrequent and usually restricted to the branches. Borer injuries in vigorously growing trees usually heal within a few months after the borers emerge, but in trees of poor vigor, up to 3 years are reguired. Galleries that heal slowly are frequently occupied by ants for nesting sites and sometimes kept open indefinitely, thus permitting the establishment of stain and decay fungi. Trunks weakened by tunnels, woodpecker excavations, and decay occasionally break during windstorms. The holes, together with the associated stain and decay, degrade the wood for any commercial use.

Description.—The adult is a typical long-horn beetle with a prominent lateral spine on each side the pronotum (Solomon 1974). The beetle is lig brown with dark elytral bands at the base and j beyond the middle of the wing covers (fig. 12A). Th are moderately robust, elongate, and range from 17 25 mm long and 5 to 8 mm wide. Females are sligh larger than males and have heavier abdomens slightly shorter antennae. The eggs are yellow white, elongate, and average 4 mm long and 1 mm diameter with a parchment-like surface texture. T larva is slightly robust, fleshy, and generally cylinc cal but very slightly flattened dorsally and ventral the thoracic segments are slightly broader anterio (fig. 12B). The color varies from white to yellow except for prominant dark-brown mandibles a amber spiracles. Larvae average 4 mm long wh newly hatched and reach 18 to 28 mm at maturi The pupa is white to greenish initially, but gradua becomes yellowish, and its eyes, mandibles, and pendages darken as adult transformation approach

Evidence of Infestation.—The earliest signs of inf tation are single or small groups of niches 4 to 8 r in diameter chewed in the bark exposing



gure 12.—*Life stages of* Goes pulcher: *(A) adult beetle; (B) mature larva.*

llowish-brown phloem beneath (fig. 13A) (Beal and assey 1942, Solomon 1974). However, the most obvi- s evidence is the sap-stained bark and yellowish ass protruding from the elongate entrance hole (fig. B). Sap oozing from the point of attack initially rkens the bark, but in succeeding years the stain comes bleached or yellowish brown. The frass ex- udes from the entrance in curved shapes or ribbon- ke pieces that accumulate on the ground below. Nu- erous excelsior-like wood fibers 8 to 12 mm long in e frass signal larval maturity and approaching pu- tion. Each borer leaves two holes, an elongate en- ance hole and a 7-mm round exit hole (fig. 13C). As ese wounds heal, the bark scar at the entrance site pears slightly sunken, with a small bulge around e periphery. The exit hole heals in much the same ay that a branch stub is overgrown. The bark scars main in evidence for several years. Wormholes 10 to mm in diameter in sawn lumber provide good evi- nce of hickory borer infestation (fig. 13D).

Biology.—The adults emerge during May and June olomon 1974). After feeding on tender twigs, leaf tioles, and leaf midribs and then mating, the female gins ovipositing. She chews an oval niche in the rk, then forces her ovipositor through the opening d downward between the bark and sapwood to lay a single egg. One female will deposit up to 14 eggs under experimental conditions on caged trees but would probably deposit many more under natural conditions. Adults live from 11 to 32 days. Females usually deposit their eggs singly, although clusters of two or three egg niches are sometimes found. Open-grown trees and those growing near openings are most frequently selected for oviposition, with a preference shown for branch crotches. The larvae produce small mines 1 to 2 cm in diameter under the bark and then bore directly into the sapwood. The galleries extend horizontally or obliquely upward in the sapwood and heartwood for 2 to 5 cm, rise vertically for another 6 to 12 cm, then turn horizontally back to the surface (fig. 13E). By the time the larva pupates, galleries range from 9 to 16 cm long and 10 to 13 mm in diameter. The life cycle is 3 to 5 years. During late fall and early spring of the final year of the life cycle, the mature larva prepares a pupation chamber at the uppermost portion of the gallery by plugging the gallery tightly with long excelsior-like fibers. Pupation lasts for 15 days. The new adult chews a round exit hole at the upper end of the pupal chamber to emerge.

Control.—Woodpeckers, one of the most important natural enemies, may capture up to one-third of the larvae (Solomon 1974). Some natural mortality is found in vigorous trees that produce heavy sap that oozes from the oviposition sites. Direct controls have not been investigated, but borers in individual trees can be controlled by injecting a fumigant into the galleries, then plugging the entrance holes with clay or putty. Where problems exist in plantings near or adjacent to forests, removal of brood trees in the adjacent woodland is advised.

BROADNECKED ROOT BORER
Prionus laticollis (L.)

TILEHORNED PRIONUS
Prionus imbricornis (Drury)

Importance.—The broadnecked root borer, *Prionus laticollis* (L.), and the tilehorned prionus, *P. imbricornis* (Drury), are pests of pecan and hickory as well as many other trees from southern Canada throughout the Eastern United States and extending west to the Plains States (Payne and others 1976, Linsley 1962). Injury occurs from the larvae feeding on and destroying the roots. The larvae feed first on the root bark, but they soon enter the wood, completely hollowing large roots and often severing them. The larvae move from root to root through the soil, feeding on the surfaces of smaller roots as they go, causing many injuries and wounds. Open-grown mature trees and those weakened by disease, drought,

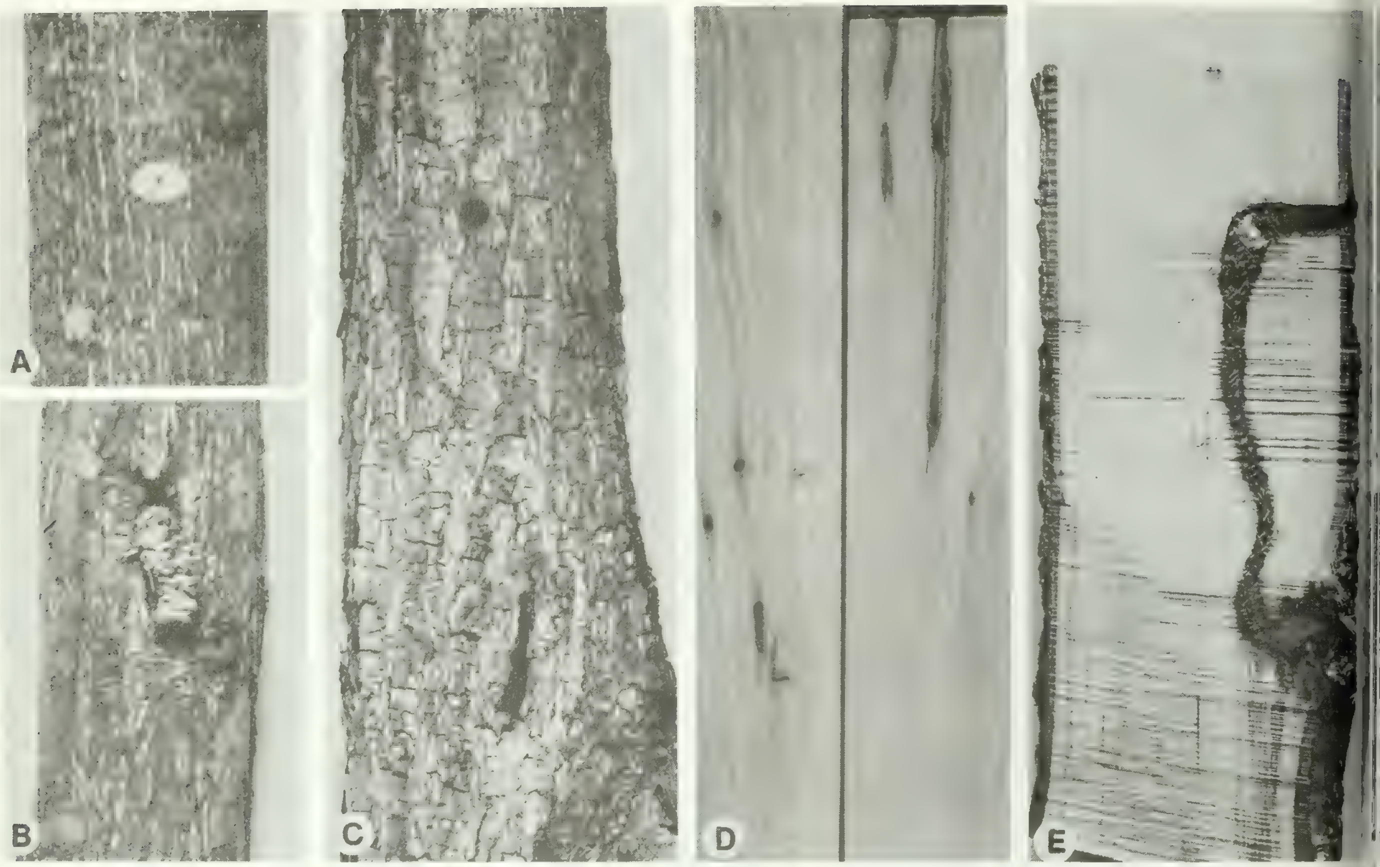


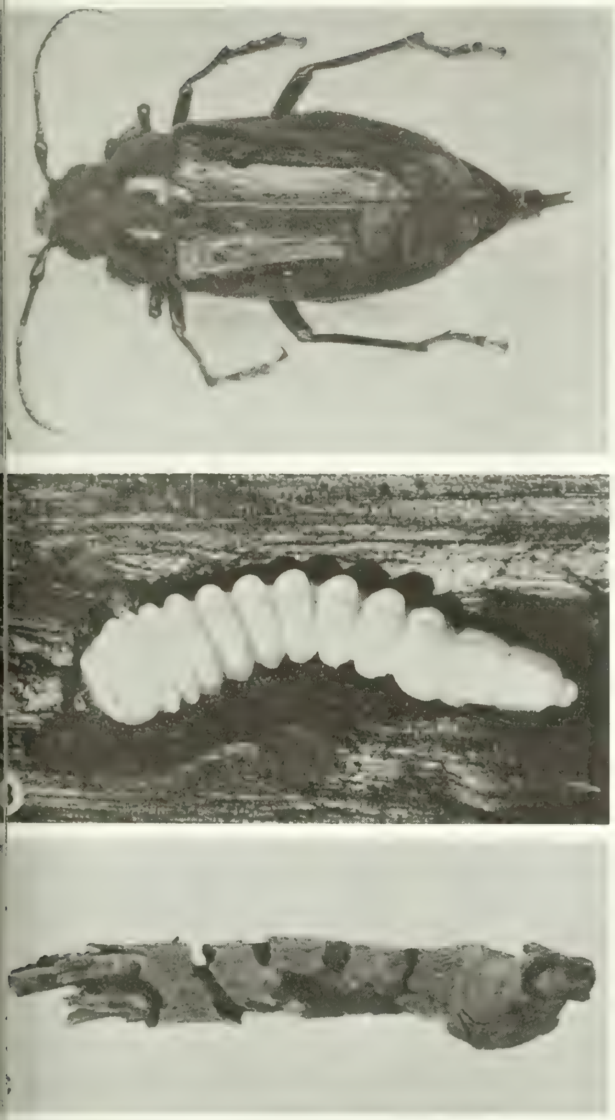
Figure 13.—*Habits and signs of infestation by* Goes pulcher *in hickory: (A) egg niche cut in bark by female beetle; (B) ribbon of frass being extruded from gallery entrance indicating active attack; (C) elongate entrance hole made by larva below and round exit hole made by adult above; (D) defects in sawn lumber; (E) sectioned stem showing typical larval gallery.*

mechanical damage, or soil conditions are most susceptible to attack, but young, vigorous trees can also be attacked and are occasionally cut off at the groundline. Severe root damage results in reduced growth, a poor nut crop, and eventual death of the tree. In southwest Georgia, pecan growers estimated that 3 to 10 percent of the trees showed signs of attack (Payne and others 1970).

Description.—The adults are robust, broad, somewhat flattened, and blackish brown to reddish brown (fig. 14A) (Linsley 1962). They have antennae about half as long as the body, and there are broad spines on each side of the prothorax. Adults of *P. laticollis* measure up to 45 mm long and adults of *P. imbricornis* measure up to 37 mm long. The eggs are irregularly punctate and glossy yellow, but later darken and lose their glossiness (Farrar and Kerr 1968). One end of the egg is slightly larger than the other. Eggs average 3.5 mm long and 1.4 mm wide. The large root-boring larvae are fleshy, elongate-cylindrical, and creamy white to yellowish; they have three pairs of small legs and small heads armed with strong mandibles adapted for boring in wood (fig. 14B) (Payne and others 1970). Mature larvae attain lengths of 9 cm or more and weigh up to 15 g. Pupation takes place inside earthen cells, and pupae are white initially, but their eyes, mandibles, and appendages darken as adult transformation approaches.

Evidence of Infestation.—Since injury to the roots occurs below ground level, correct diagnosis is often difficult (fig. 14C) (Payne and others 1970). Only by excavating the tree and examining the roots can one confirm the infestation (fig. 15A, 15B). The aboveground syndrome is a gradual decline, characteristic of any tree under severe, prolonged stress (fig. 16). Symptoms often resemble a nutrient deficiency—leaves may be sparse, reduced in size, and have a light-green to yellowish tinge. Nut yields from infested trees may be three to seven times less than from healthy trees. As an infestation progresses over a period of several years, 70 to 90 percent of the root system may be destroyed, resulting in a limb-by-limb death of the tree (Sparks and others 1974).

Biology—Adults emerge from the soil in late spring and early summer (Baker 1972, Benham and Farrar 1976). The beetles are normally nocturnal or crepuscular in habit and during the day remain hidden beneath debris or loose bark at the base of the tree. The females are short-lived—about 1 week—but deposit 300 to 500 eggs either singly or in groups in the soil



Fure 14.—*Life stages of and injury from* Prionus *spp: (A) adult beetle; (B) mature larva; (C) pecan root girdled and hollowed by larvae.*

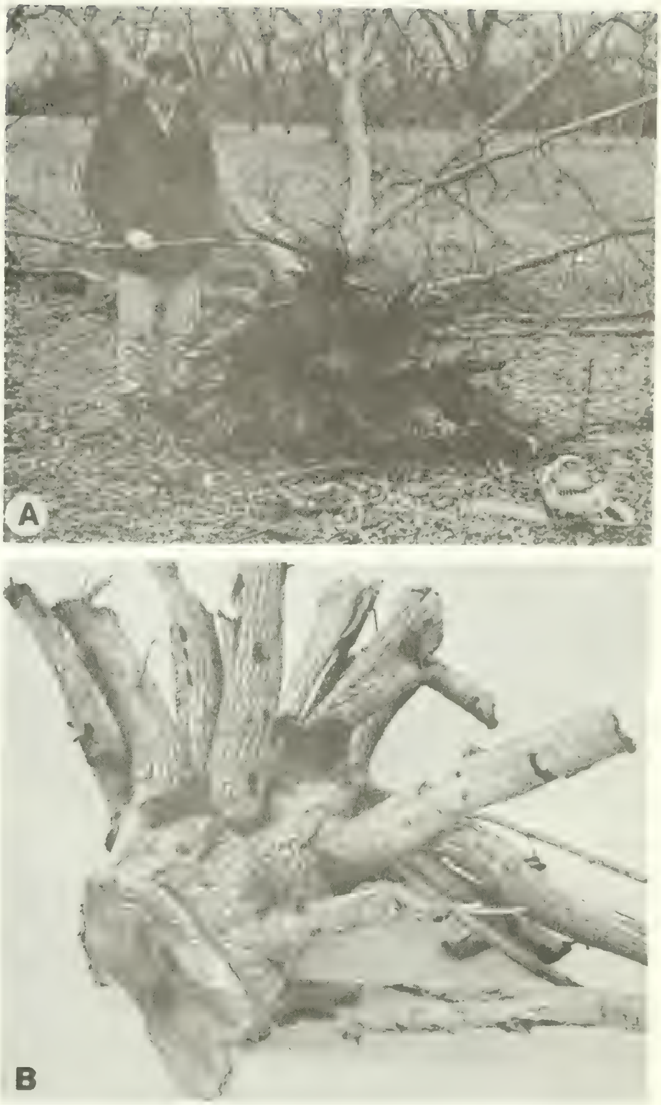


Figure 15.—*Diagnosing for* Prionus *spp. in pecan: (A) excavating roots to confirm* Prionus *infestation; (B) closeup of root system showing holes and girdling—most of smaller roots have been consumed by the larvae.*

nar the base of host trees. When the eggs hatch in 2 t3 weeks, the young larvae dig down to the roots and bgin feeding on the bark. They move from root to root trough the soil feeding on the surfaces of smaller rts as they go and causing many injuries and wunds. They enter the wood of larger roots and hollv, girdle, or sever them. In the summer, the larvae fd on roots in the upper 15 to 45 cm of the soil, but i winter they are often found at depths down to 8 cm. The feeding period lasts 3 to 5 years. In early sring, mature larvae come to within 6 to 12 cm of the sl surface and prepare large, oval earthen cells in vich they pupate and transform to the adult stage.

ontrol.—Root borers usually attack trees weakeed by other factors such as disease, drought, mechanical damage, or soil conditions (Sparks and others 1974). Therefore, cultural practices should be followed to keep trees thrifty and vigorous. Since these root borers are also pests of other tree species, it is advisable to establish new plantings some distance away from orchards and tracts of woodland that are already infested. Although little is known about natural enemies, they undoubtedly play a role in regulating root borer populations. A tachnid parasite (near *Dexilla)* has been reared from *P. laticollis* (Benham and Farrar 1976), and several bacteria and fungi have been isolated from dead larvae and pupae of *P. laticollis*. It may be necessary to use insecticides occasionally if root borer populations threaten high-value trees (Payne and others 1976).

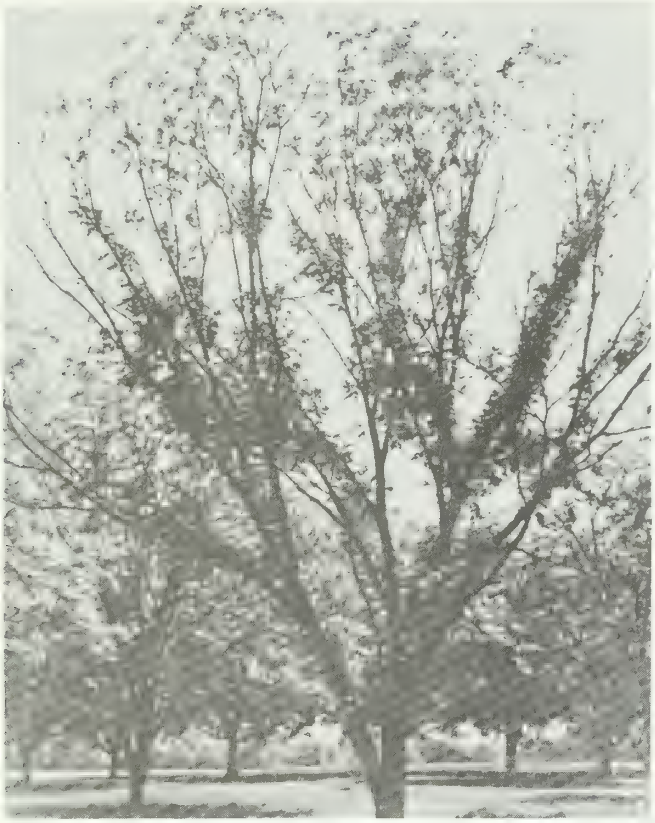


Figure 16.—*Pecan tree in declining condition—symptoms of root injury by* Prionus *spp.*

TWIG GIRDLER
Oncideres cingulata (Say)

Importance.—The twig girdler, *Oncideres cingulata* (Say), a pest of pecan and hickory, and to a lesser extent several other hardwood species, is found most commonly in the Southern States but is known as far north as New England and westward to Arizona (Gill 1924, Herrick 1904, Beal and Massey 1942). The adult beetles girdle twigs and small branches causing the injured portions to break away or hang loosely on the tree. It is not uncommon to see the ground under infested trees almost covered with twigs that have been cut off. This affects the beauty and aesthetic quality of ornamental plantings. The fruiting area of heavily infested trees is often greatly reduced, resulting in low nut yields the following year and sometimes longer. This type of injury causes the development of many offshoots that adversely affect the symmetry of the tree. Pecan nurseries located close to heavily infested woodlots occasionally suffer considerable loss from girdled seedlings. Repeated girdling of terminals causes forks, crooks, and other stem deformities in young timber plantations as well as in natural reproduction (Kennedy and others 1981).

Description.—The adults are typical long-horne
beetles that range from 12 to 16 mm in length (fig
17A) (Bilsing 1916, Gill 1924, Herrick 1904). Th
body is cylindrical and generally grayish brown wit
a broad, ashy-gray band across the middle of the win
covers. The eggs are white, elongate oval, and abou
2.5 mm in length. The larvae are whitish, cylindrical
legless grubs that reach 16 to 25 mm in length a
maturity (fig. 17B). The pupae are white with short
dark spines on the dorsal sides of segments.

Evidence of Infestation.—The presence during lat
summer and fall of severed twigs on the ground, hang
ing loosely attached or lodged in the canopy is goo
evidence of infestation (Gill 1924, Herrick 1904). Mos
girdled twigs are from 6 to 12 mm—occasionally rang
ing up to 18 mm—in diameter, and 30 to 60 cm i
length. The nature of the girdle itself distinguishe
the twig girdler from other branch pruners. The cu
by the twig girdler is the only one made from th
outside by the adult beetle and has been described a
a uniform V-shaped cut (fig. 17A). The cut is seldon

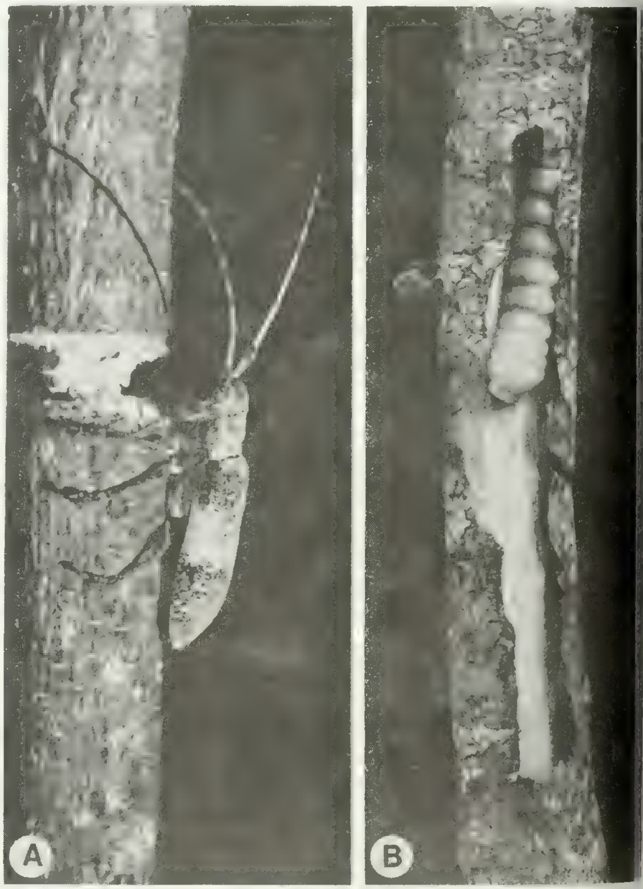
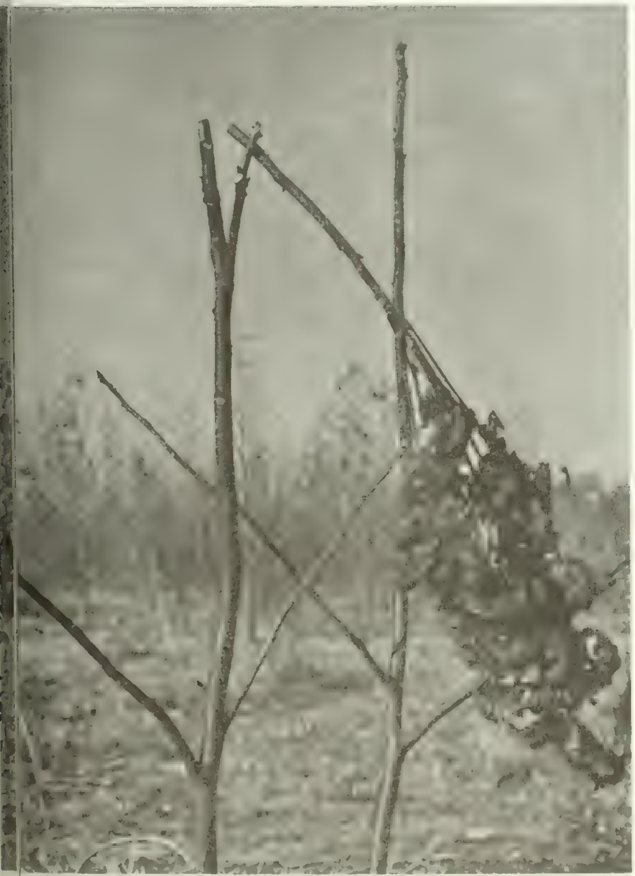


Figure 17.—*Life stages of* Oncideres cingulata: *(A) adult beet girdling pecan stem; (B) mature larva in gallery.*

mplete, leaving a small center with a jagged surface aused by the break. Since the twigs are girdled while e leaves are present, the severed twigs retain the rown leaves for some time (fig. 18). Severed twigs dged in the tree canopy or on the ground often retain aves even after the tree sheds its leaves in the aumn. Close inspection of the severed twigs will reeal tiny egg niches and many mandible marks or rooves made in the bark by the female beetles. Large ees usually sustain the most girdling, but young antation trees are sometimes heavily damaged g. 19).

Biology—The adults emerge from late August to rly October (Bilsing 1916, Gill 1924, Herrick 1904). hey feed on the tender bark near branch ends and ate before ovipositing and girdling the twigs. The anches are apparently girdled by the female so that ngenial conditions will be provided for the developent of the larvae, which are unable to survive in ying twigs. The girdling extends through the bark d well into the wood in a complete circle around the em and leaves only a thin column of the center wood tached, which breaks easily (fig. 17A). Eggs are laid ring or after the cutting process, but never before e beetle makes part of the cut. They are inserted singly beneath the bark or slightly into the wood, usually near a bud scar or adjacent to a side shoot. The number of eggs per twig varies from 3 to 8 but may range up to 40. Adults live 6 to 10 weeks. Females deposit 50 to 200 eggs each, which hatch in about 3 weeks. After overwintering, the larvae grow rapidly in the spring and tunnel toward the severed end of the twig by feeding only on the woody portion and leaving the bark intact. A few small circular holes are made in the bark to eject pellets of frass and excrement. The mature larvae close off the gallery with shredded fibers to form a pupation chamber. Pupation occurs during August and September and lasts 12 to 14 days. The adult chews a circular hole in the bark to emerge. There is one generation per year.

Control.—In orchards, nurseries, and ornamental plantings, the severed twigs on the ground as well as those lodged in the trees should be gathered and burned during the fall, winter, and spring when the eggs and grubs are in the twigs (Gill 1924, Moznette and others 1931). The same practice should be followed in nearby woodlots when plantings in the vicinity have a history of serious damage from this insect pest. Insecticides may be necessary to prevent damage from heavy infestations, although they are probably



F ure 18.—*Main stem of young tree girdled by* Oncideres cingulata.

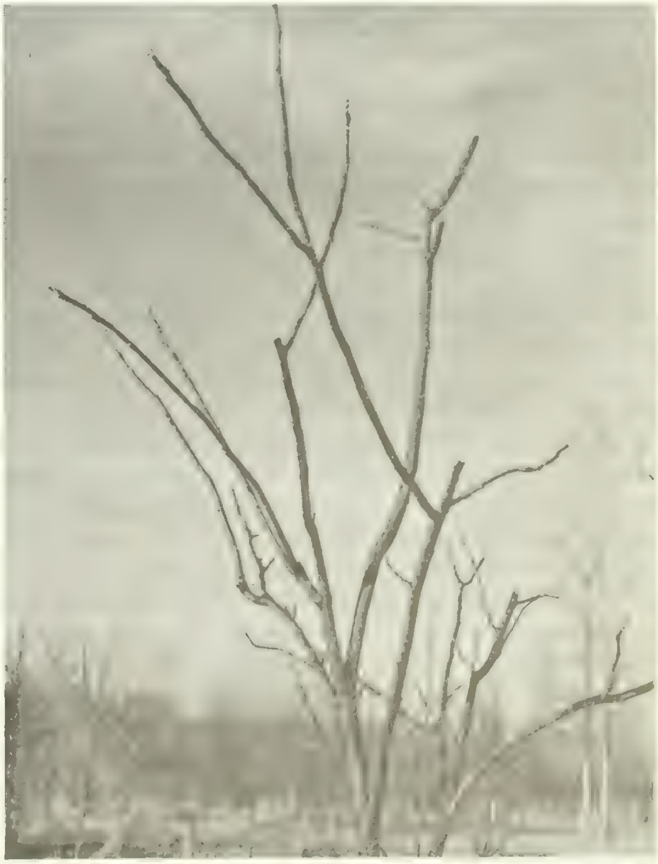


Figure 19.—*Young plantation tree with terminal and most of branches girdled by* Oncideres cingulata.

unnecessary in natural forest stands. Natural controls are important in keeping twig girdler populations low; desiccation of the eggs is apparently the greatest single decimating factor. Three parasites: an eurytomid, *Eurytoma magdalidis* Ashm., one ichneumonid, *Iphiaulax agrili* (Ashm.), and one eulophid, *Horismenus* sp., help to reduce the girdler population (Beal and Massey 1942). A clerid predator, *Cymatodera undulata* Say, has also been reared.

TWIG PRUNER

Elaphidionoides villosus (F.)

OAK TWIG PRUNER

Elaphidionoides parallelus Newman

Importance.—The twig pruner, *Elaphidionoides villosus* (F.) and oak twig pruner, *E. parallelus* Newman, are found throughout the Eastern United States northward to Canada and westward to Texas, reaching greatest importance in their northern range (Chittenden 1910, Linsley 1963, Moznette and others 1931). They attack pecan and hickory as well as other forest, shade, and fruit trees but show a marked preference for the oaks. The larvae, boring in the stems, cut off or prune twigs and small branches. Pruned twigs drop to the ground or hang loosely from partially severed branches. The ground under heavily infested trees may be littered with fallen twigs and branches. Such pruning and littering adversely affect the aesthetic quality of ornamental plantings and cause clean up problems; heavy twig losses reduce the fruiting area and, in turn, the nut crop; and young trees may be deformed. Injuries to trees in natural stands are seldom serious.

Description.—The adult beetles are elongate, slender, and parallel-sided (fig. 20A) (Chittenden 1910, Linsley 1963). The bodies are light to dark brown and clothed with irregular patches of fine gray hairs giving them a mottled appearance. There are spines on the first few joints of the antennae and the tips of the wing covers are notched and bispinose. They range from 12 to 18 mm in length. *Elaphidionoides villosus* resembles *E. parallelus* very closely, but *E. parallelus* is usually slightly smaller and somewhat more slender. The larvae are elongate, cylindrical, and creamy white; they have short rudimentary thoracic prolegs and measure about 14 to 22 mm in length at maturity (fig. 20B).

Evidence of Infestation.—During the summer, fall, and winter pruned twigs from 8 to 20 mm in diameter and from 20 to 90 cm in length litter the ground under infested trees (Gill 1924, Moznette and others 1931). Pruned twigs may also hang from the crown. The nature of the girdle itself distinguishes the twig pruners from the twig girdler and branch pruner. The cut by twig pruners is made from inside by the larva, whi gnaws a circular groove in the wood, leaving only t bark intact. The severed end of the twig presents smoothly cut surface, near the center of which is oval 2-mm gallery opening often plugged lightly wi frass (fig. 21). A smaller side-twig is usually hollow out and may be broken in its fall to the ground. The are no egg niches or mandible marks on the ba surface as seen with the twig girdler. Moreover, spli ting the freshly pruned twig reveals the nearly grow twig pruner larva inside, while the twig girdler eith has not hatched or the larva is too small to be notic until the following spring and summer.

Biology.—The adults emerge from early spring early summer (Chittenden 1910, Gosling 1978). T female deposits her eggs in slits in the bark at le axils near the tips of very small green twigs that ari from a larger twig 8 to 20 mm in diameter. The you larva burrows down the center of the twig toward i base, hollowing it out more or less completely. Wh the larva reaches the larger limb, it bores into t branch and burrows a short distance down the cent of the stem. In late summer or fall the larva severs t branch by making concentric circular cuts from t

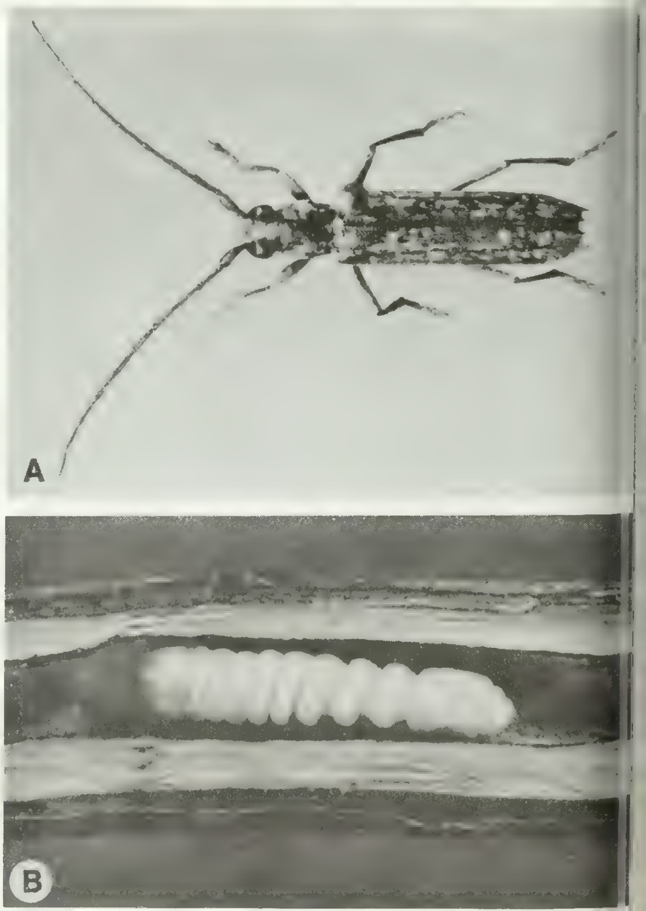
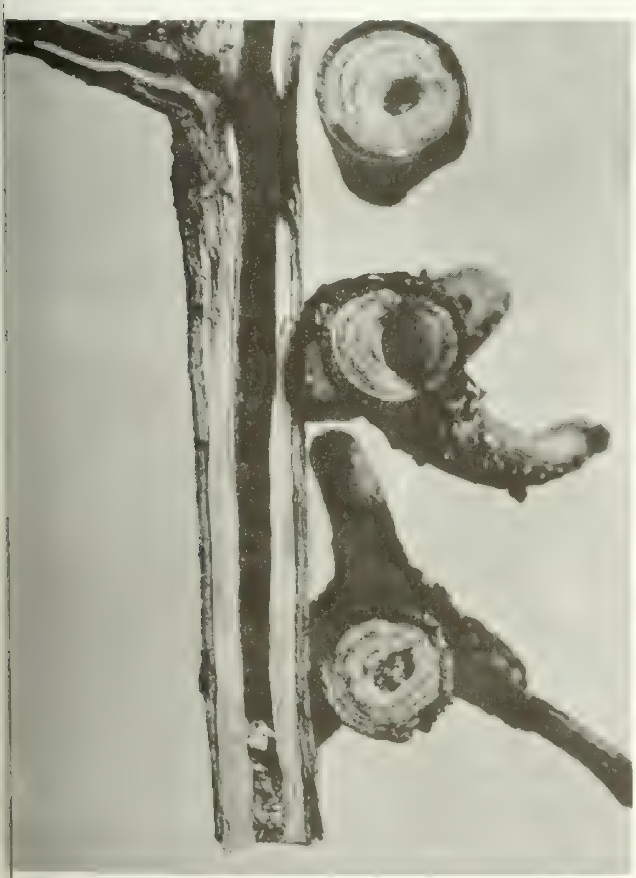


Figure 20.—*Life stages of* Elaphidionoides *sp: (A) adult bee*
(B) mature larva.

nter outward to, but not including, the thin bark. evered branches later break and fall to the ground ith the larvae in them. The larva retreats back into s burrow and plugs the oval gallery at the severed d with small fibrous frass and pupates within the urrow the following spring. There is usually one gen- ation per year, but a 2-year generation life cycle has en reported for *E. parallelus* in its northern range osling 1978).

Control.—Control of twig pruners in orchards, urseries, and ornamental plantings is similar to that r the twig girdler (Chittenden 1910, Gill 1924). That i all severed twigs on the ground or lodged in the ee should be collected during fall and winter and stroyed while the grubs are still in the twigs. To be ost effective, the severed twigs should be collected er the entire orchard, woodlot, or neighborhood. In- scticides are rarely needed; natural controls help to ep infestations in check. Two braconid parasites, *racon eurygaster* Brulle and *Odontobracon elaph- ibrus* Rohwer, have been recovered from the twig uner (Linsley 1963), while two braconids, *Meteorus bialis* Muesebeck and *Iphiaulax eurygaster* Brulle, e ichneumonid, *Agonocryptus discoidaloides* ereck, and one tachinid, *Minthozelia ruficauda* Reinhard, were reared from the oak twig pruner (Gosling 1978). The downy woodpecker, *Dryobates pubescens* L., blue jay, *Cyanocitta cristata* L., and black-capped chickadee, *Parus atricapillus* L., have been reported to destroy large numbers of the twig pruner (Chittenden 1910). A spider, *Theridium tepidariorum* C. Koch, has also been observed preying upon the twig pruner. Rodents, such as squirrels, have destroyed up to 31 percent of the oak twig pruner population in Michigan studies (Gosling 1978).



F ure 21.—*Larval gallery and ends of twigs severed by* Elaphidionoides *sp. Note oval holes with frass plugs in ends of severed twigs.*

BRANCH PRUNER

Psyrassa unicolor (Randall)

Importance.—The branch pruner, *Psyrassa unicolor* (Randall), attacks pecan and hickory, and to a lesser extent the oaks and a few other species throughout the Eastern United States from Minnesota south to Alabama and west to Texas (Linsley 1963). The larvae tunneling in the stems cut off or prune large branches. Pruned branches, due to their size and weight, usually drop to the ground; they seldom hang loosely from partially severed branches as seen with the twig girdler and the twig pruner. Although individually pruned branches are generally larger than those girdled by the twig girdler or the twig pruner, the number of pruned branches is usually less. Although individual shade and ornamental trees and occasionally orchard trees may be seriously pruned, entire stands or groves seldom sustain economic damage.

Description.—The narrow, elongate adults are colored light to reddish brown, have short and inconspicuous pubescence, and are coarsely punctured (fig. 22A) (Linsley 1963). The antennae are about as long as the body in the female and slightly longer in the male. In length, females range from 9 to 13 mm and males 7 to 11 mm. In width, females average 2.2 mm and males 1.8 mm. The larvae (fig. 22B) are slender, elongate, cylindrical, and whitish with dark-brown mandibles; they have yellowish thoracic shields, very short rudimentary thoracic prolegs, and measure about 12 to 18 mm long at maturity.

Evidence of Infestation.—Branches are pruned and fall to the ground during spring as opposed to summer, fall, and winter for those cut off by the twig pruners and twig girdler. Pruned branches are often much larger than those cut off by other pruners and girdlers, ranging from 10 to 50 mm in diameter and 0.6 to 3.6 m long. Pruned branches generally fall free to the ground, seldom hanging from the tree by the severed end as is true for the other pruners and girdlers (fig. 23A). The cut made by the branch pruner is similar to that of the twig pruner in that is is made from the inside by the larva, which chews a uniformly smooth, circular cut in the wood, leaving only the

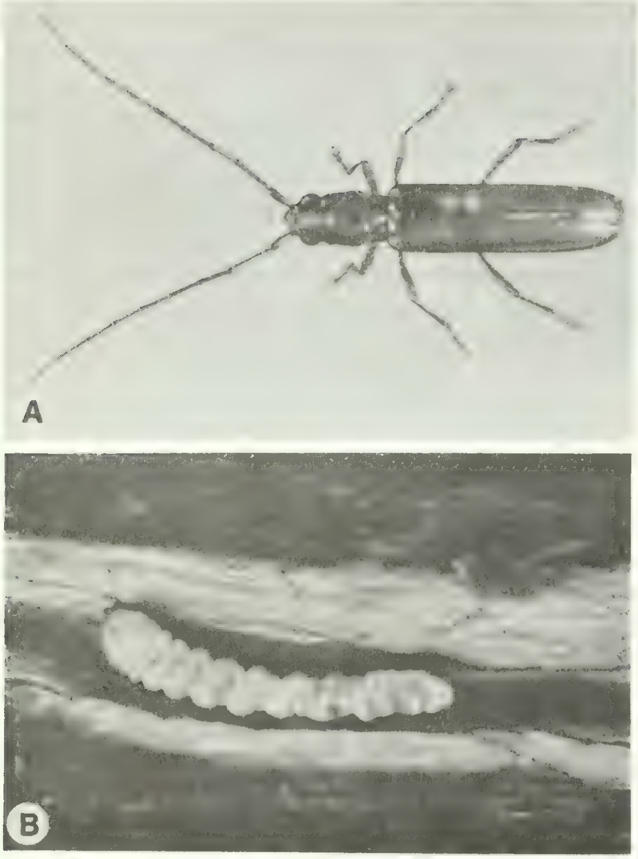


Figure 22.—*Life stages of* Psyrassa unicolor: *(A) adult beetle; (B) matura larva.*

bark intact (fig. 23B). It differs from the twig pruner in that the larval hole is not at the center of the twig, but instead is near one side, usually just below the bark near a small side-twig, and the hole is often plugged with frass. Although the larva usually tunnels in the pruned branch, it will sometimes tunnel in the pruned stub still on the tree.

Biology.—Adults emerge from late April to early June. Eggs are deposited on small twigs that arise from a larger branch 10 to 50 mm in diameter. The young larva tunnels down the center of the twig toward its base, but it does not hollow out the small twig as completely as *Elaphidionoides* spp. Upon reaching the larger branch, it bores into the branch and begins to girdle it. The girdle is completed during late winter and spring when the larva makes a smooth, uniform concentric circular cut, often completely severing the wood, but leaving the bark intact (fig. 23B). Severed branches may break at any time, but breakage occurs mostly during spring windstorms. If breakage does not occur immediately, the larva usually tunnels into the severed portion of the branch just beneath the bark near the junction of the small twig. Here it tunnels toward the center of the stem for 15 to 30 mm then back toward the surface, and finally tunnels distally just under the bark for 30 to 80 mm (fig. 23C). A

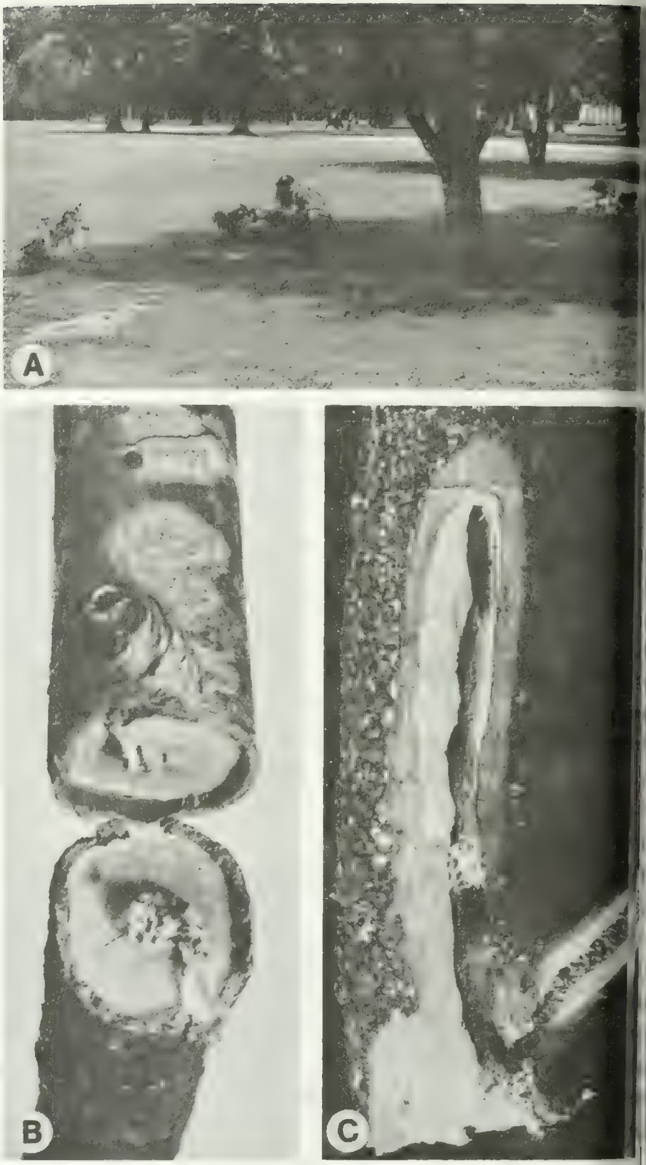


Figure 23.—*Evidence of infestation by* Psyrassa unicolor *in peca*
(A) large severed branches have fallen to groun
(B) severed branch illustrating nature of larval cu
(C) larval gallery extending from small side branc
into severed main branch.

small number of larvae, however, tunnel basally fro
the point of girdle. Larvae are sometimes dislodged
the time of the break and fall to the ground and d
Some retreat into the small twig before the bran
breaks. Pupation takes place within the gallery ju
beneath the bark. The adult chews an irregula
shaped hole through the bark to emerge. Althou
the life history is little known, a generation app
ently requires 1 to 2 years.

Control.—Severed branches on the ground un
trees in orchards and ornamental plantings should
picked up in the spring and destroyed before t
adults emerge in late spring and early summer. To
most effective, the pick-up and destroy practice sho

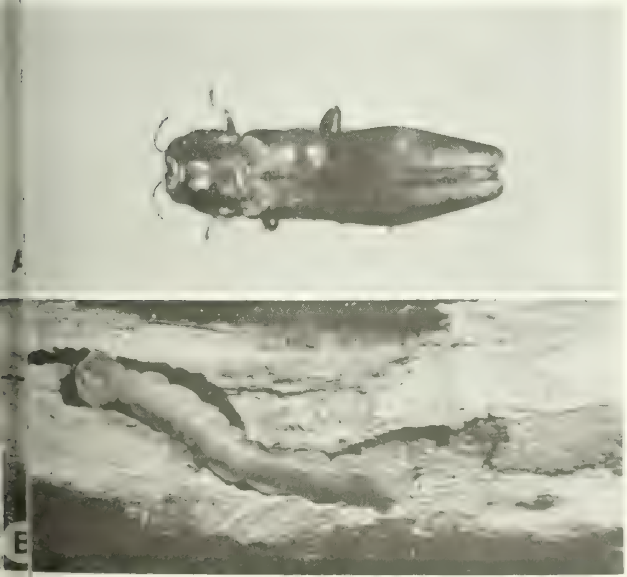
done for the entire orchard, woodlot, or neighbor- od. Direct control in natural forest stands is rarely eded. Two icheumonid parasites of *P. unicolor,* *bena grallator* Say and *Agronocryptus dis- daloides* Viereck, help to reduce infestations (Lins- 1963).

HICKORY SPIRAL BORER
Agrilus arcuatus Say

nportance.—The hickory spiral borer, *Agrilus ar- tus* Say, is primarily a pest of pecan and hickory occasionally attacks other deciduous species ughout the eastern half of the United States (Beal Massey 1942, Brooks 1926). Twigs, branches, and ninals up to 40 mm in diameter on trees of all sizes y be severed. Many of the severed branches break drop to the ground. Serious damage to large trees lts in reduced nut production, ragged appearance, poor tree symmetry. Repeated attacks on young roduction may cause stunted, misshapened, ked, and forked stems. Although individual trees be seriously damaged, entire stands, groves, series, and other plantings are seldom badly dam- l. Serious damage is most likely to be found in tings adjacent or close to forested tracts contain- many heavily infested hickories.

escription.—The adults are dark, slender restid beetles (fig. 24A) (Brooks 1926). The head thorax of the male are greenish bronze, the wing rs are purplish black, and the underparts are sy; the female is bronze in color throughout. The age length of males is 8 mm and that of females t 10 mm. Eggs are flat, disklike in shape, 0.8 to 1.1 mm in diameter, and glued firmly to the smooth bark of the twigs. They resemble the shield of a small scale insect. Initially the eggs are smooth and pale yellowish green, but before hatching they become slightly wrinkled and almost black. The larva is a slender, flat, legless grub, with full-grown specimens reaching 15 to 20 mm long and 2 mm wide (fig. 24B). They are yellowish white except for dark brown or black mouth parts and tail forceps.

Evidence of Infestation.—Branches and terminals are severed during the winter and spring (fig. 25) (Baker 1972, Brooks 1926). The portion above the girdle usually dies in the spring before the foliage appears, the injury becoming apparent as the rest of the tree puts forth leaves. Severed branches may break and fall to the ground either before or after bud-break in the spring. Stems 8 to 40 mm in diameter and 0.5 to 2.5 m long may be severed; although many of these stems are larger than those girdled by twig girdlers and twig pruners, on the average they are slightly smaller than those pruned by the branch pruner. The spiral cut made by the larva is a characteristic winding, concentric cut from the inner bark to the heart of the branch or stem, the coils of the thin burrow joining and completely severing the wood except for the bark and sometimes a slender fiber of wood at the center (fig. 26A).



ig 24.—*Life stages of* Agrilus arcuatus: *(A) adult beetle; (B) nearly mature larva.*

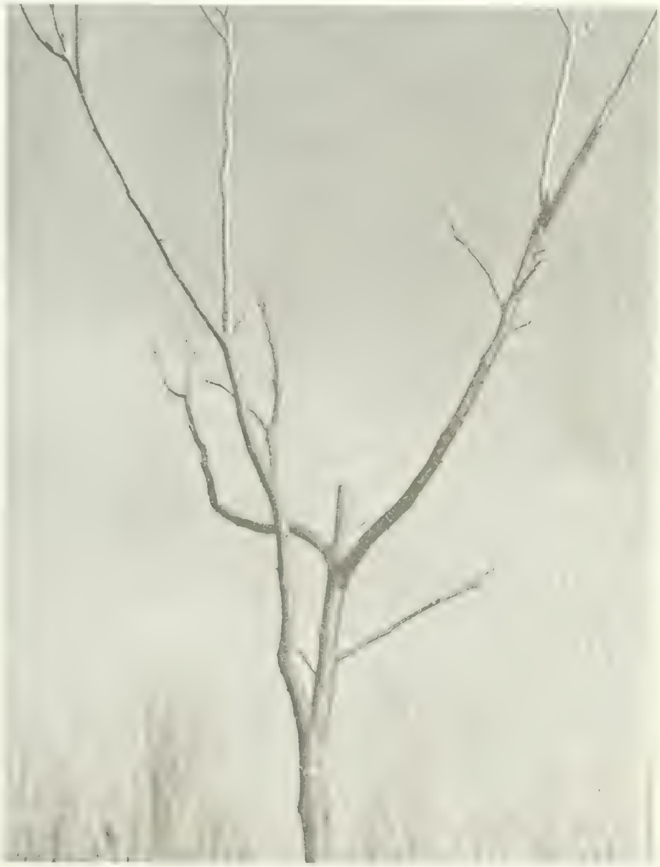


Figure 25.—*Young hickory with main stem severed by* Agrilus arcuatus.

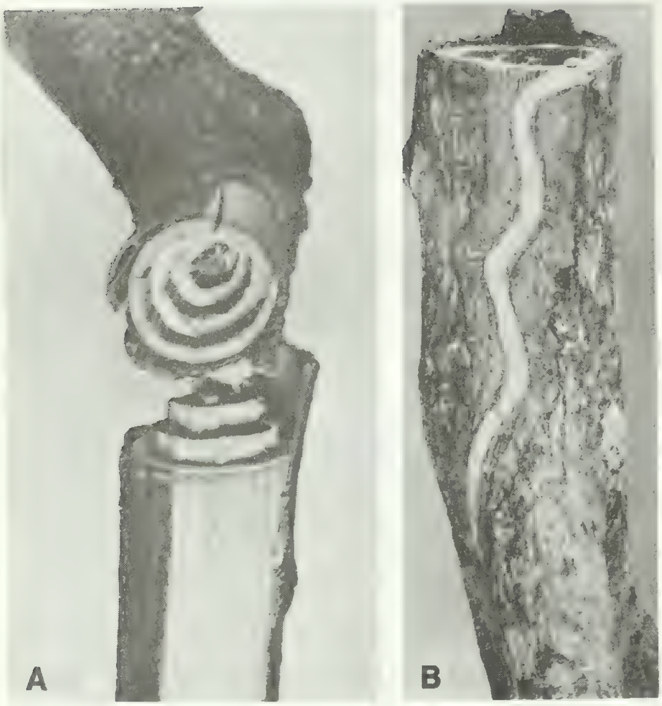


Figure 26.—*Characteristics of injury by* Agrilus arcuatus *in hickory: (A) severed branch illustrating spiral cut made by the larva; (B) bark removed to expose larval mine leading to the spiral cut.*

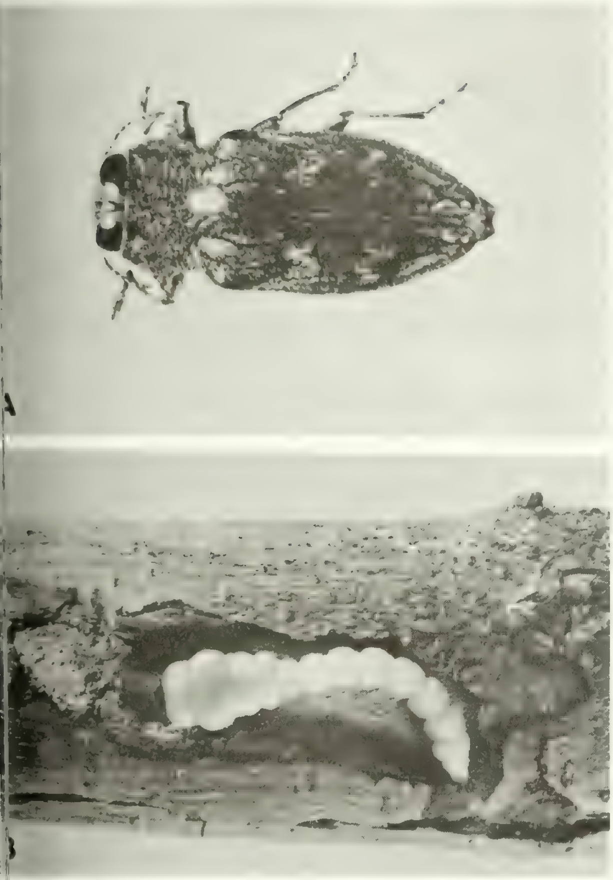
Biology.—Adults emerge from late April to late June, depending on location, and feed on the foliage, making elongate notches and slits in the edges of the leaves (Brooks 1926, Ruggles 1918). Females begin oviposition 10 to 14 days after emergence. A single egg is deposited on the bark surface of terminal or lateral twigs, usually near the base of a small shoot of the current season's growth, and is covered with a transparent secretion that glues the egg to the bark. Each female lays from 2 to 55 eggs over a period of 1.5 to 2 months. The eggs hatch in 3 to 4 weeks. The larva hatches by chewing its way through the bottom of the egg chorion and directly into the twig. In the twig it makes an elongate threadlike burrow under the bark. Late in autumn it begins a spiral burrow, partially severing the twig by spring. The mining larva packs the gallery behind itself with fine wood dust. During the second summer it mines basally under the bark along the stem for 20 to 60 cm leaving a shallow but relatively wide burrow packed with brown-colored frass (fig. 26B). During late fall it changes its course abruptly and cuts a thin symmetrical ring around the stem. When the first circuit is completed, it bores spirally inward, encircling the stem until the stem center is reached. The larva then turns upward toward the bark where it mines under the bark for 25 to 76 mm where it forms a crescent-shaped pupal chamber. The ends of the chamber extend to the bark, and the bottom curves toward the stem center. Both ends of the pupal chamber are plugged with frass. Pupation occurs during May and June and lasts about 3 weeks. The adult gnaws a D-shaped hole in the bark 25 to 76 mm above its spiral burrow to emerge from the pupal chamber. A generation requires 2 years.

Control.—Young trees in heavily infested nurseries and orchards should be pruned to remove the killed branches and terminals as soon as leaves develop in the spring in order to collect and destroy the larvae (Beal and Massey 1942, Brooks 1926, Ruggles 1918). Special care should be taken to remove the small dead twigs that have been severed by the first-winter larvae. Such twigs should be clipped several centimeters below the dead part in order to make sure of getting the borer. Also, any severed branches or terminals should be picked up and destroyed promptly before adult emergence begins. Three parasites, an ichneumonid, *Labena apicalis* Cress., a braconid, *Monogonogastra agrili* Ashm., and pteromalid, *Za pus* sp. (near *nigroaeneus* Ashm.), help reduce populations (Brooks 1926).

FLATHEADED APPLETREE BORER
Chrysobothris femorata (Olivier)

Importance.—The flatheaded appletree borer, *Chrysobothris femorata* (Olivier), is a pest of pecan and hickory as well as many other deciduous trees, extending from Mexico throughout the United States into Canada (Baker 1972, Brooks 1919). It generally attacks trees that have recently been transplanted, stressed from various causes, or have bark that has been damaged by tools, disease, rodents, sun scald or other insects. Injury results from the larvae tunneling in the bark and cambium area. Trees of all sizes may be attacked; those 5 cm or less in diameter may be girdled and killed, and larger trees may be severely weakened and scarred. Since wooded tracts often harbor high populations of beetles, damage is usually most pronounced when plantings are made in close proximity to woodland or old declining orchards.

Description.—The adult is a broad, oval, flattened beetle about 7 to 16 mm in length (fig. 27A) (Brooks 1919, Moznette and others 1931). The beetle is metallic colored and indistinctly marked with spots and irregular bands of dull gray. The underside is a coppery-bronze color and the sides beneath the wings are a metallic greenish blue. The egg is pale yellow, flattened, disklike, wrinkled, and about 1.5 mm in diameter. It is firmly attached to the bark by its flat surface. The larva is yellowish white, legless and about 25 mm long when fully grown (fig. 27B). The three thoracic segments are much broadened and compressed, giving the larva the appearance of having a large flattened head, which accounts for the name "flathead." The larvae within their galleries



ıre 27.—*Life stages of* Chrysobothris femorata: *(A) adult beetle; (B) nearly mature larva.*

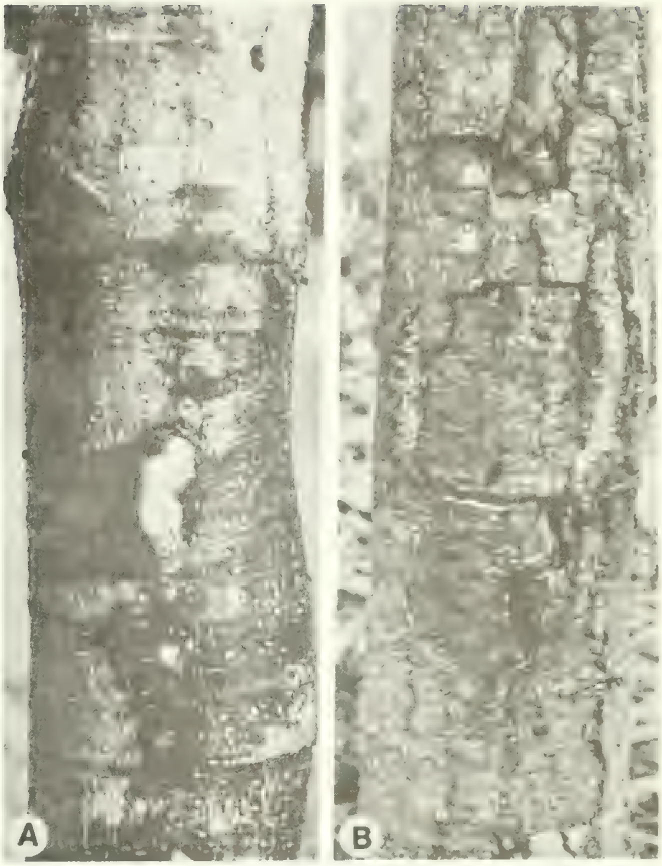


Figure 28.—*Signs of infestation by* Chrysobothris femorata: *(A) frothy sap oozing from bark is early symptom of infestation; (B) bark depressions, loosened bark, and oval exit hole provide evidence of infestation.*

ırly always assume the curved shape of a horse-
e. The pupa is somewhat more yellow than the
va and resembles the adult in structure.

vidence of Infestation.—Points of infestation can
ally be detected by white, frothy sap oozing from
cks in the bark (fig. 28A) (Fenton 1942, Brooks
9, Moznette and others 1931). The bark gradually
umes a darkened, wet or greasy appearance. Little
no frass is ejected except at cracks in the bark.
ıred areas usually become depressions, and later
bark may split at the injured sites (fig. 28B). At-
ks occur most often on the sunny aspect of the tree.
burrows under the bark are broad and irregular
filled tightly with fine, sawdustlike frass. In
ng trees with thin bark, the tunnels are usually
g and winding, sometimes encircling the tree. In
r trees with thick bark, the burrows are confined
circular area under the bark. Wounds may be
rged year after year by succeeding generations.
mentioned previously, attacks are often associated
n injuries. Trunks may be attacked at any point
ve ground level; branches may also be attacked.

iology.—Adults appear from March to November,
they are most abundant during May and mid-
gust to mid-September (Fenton 1942, Moznette and others 1931). Beetles are active, run rapidly, and take flight quickly when disturbed. On hot, clear days, they may be found on the sunny side of trunks and larger branches. The female spends much time running over the surface, probing the bark with her ovipositor for places to oviposit. Females mate and begin ovipositing in 4 to 8 days; they live about 1 month after emergence. Each female lays about 100 eggs, depositing them singly in cracks or crevices of the bark, under bark scales, and at bark injuries. Eggs hatch in 8 to 16 days. The newly hatched larva chews through the bark and feeds in the phloem and surface of the sapwood. In trees sufficiently weakened, the larvae produce long tortuous burrows and develop rapidly. In more vigorous trees, larval development is slow and many larvae die, probably due to heavy sap ooze. As soon as the larva is fully developed, it tunnels from the cambium area radially into the sapwood where a pupal chamber is prepared by plugging the burrow tightly with frass. Here it overwinters as a larva. The larva pupates during the following spring or summer. The pupal stage lasts about 8 to 14 days. Adults emerge by cutting small oval emergence holes through the bark (fig. 28B). Nor-

mally there is one generation per year, but some generations require 2 to 3 years.

Control.—Because flatheaded borers rarely injure healthy, vigorous trees, cultural methods should be selected that keep trees vigorous, such as proper transplanting, cultivation, fertilization, spraying, pruning, thinning, and irrigation (Baker 1972, Brooks 1919, Fenton 1942, Moznette and others 1931). Since young transplanted trees are under stress and particularly susceptible, additional measures may be warranted such as wrapping the trunks with a double thickness of newspaper, burlap, or crepe paper from the ground to the lower limbs to prevent oviposition (fig. 29), or by shading the trunks from sunlight to deter the ovipositing females. Painting the trunks white to reduce injuries from sun scald may also help. Injuries by equipment, storm, frost, and other causes should be minimized and any fresh wounds promptly painted with pruning compound. Borers may be removed from individual trees with a knife, being careful to avoid unnecessary cutting and damage. All dead and dying trees and all pruned branches should be removed from ornamental and orchard plantings to reduce breeding sites for the beetles. Natural enemies also help to reduce flatheaded borer populations. Two ichneumonids, *Lab* *grallator* Say, *Cryptohelcostizus chrysobothri* Cushman, one chalcid, *Phasgonophora sulcata* We wood, and one braconid, *Atanycolus rugosiven* Ashm., are parasites of flathead borers; two cler *Chariessa pilosa* (Foster) and *C. pilosa onusta* S one asilid, *Andrenosoma fulvicauda* Say, and wo peckers are predators.

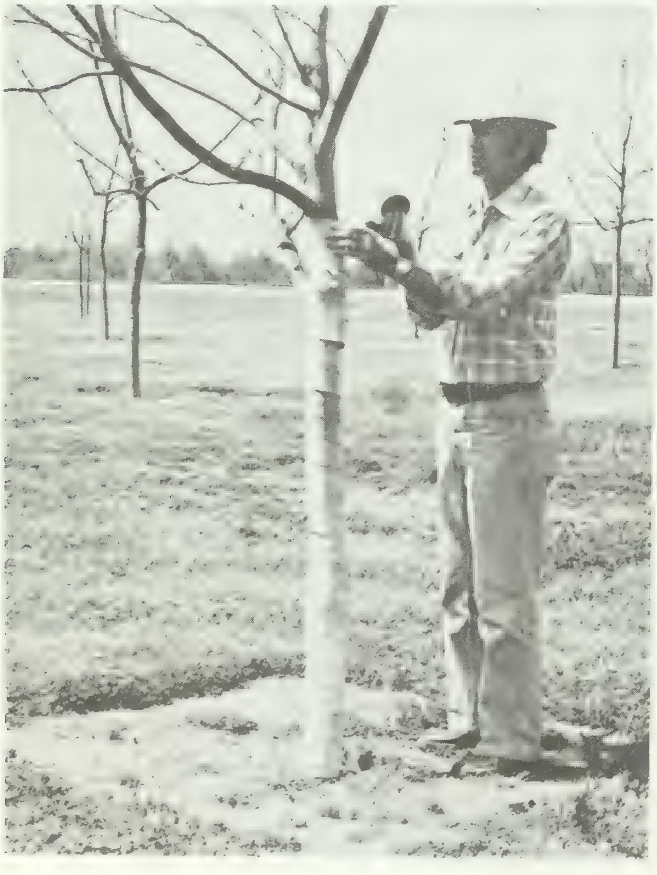


Figure 29.—*Wrapping trunk of young transplanted pecan tree with crepe paper for protection from* Chrysobothris femorata.

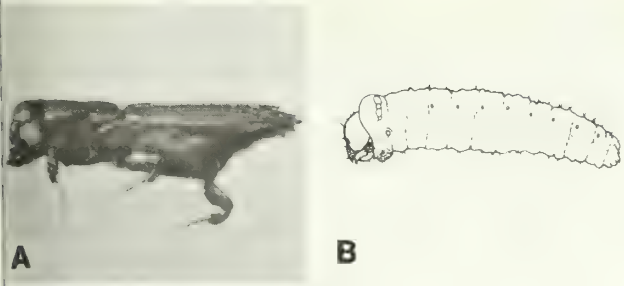
PIN-HOLE BORERS

Platypus compositus (Say) and *Xyleborus* spp.

Importance—The pin-hole borers, *Platypus co-* *positus* (Say), *Xyleborus affinis* Eichoff, *X. ferrugin* (F.), and *X. saxeseni* (Ratzeburg), also called ambro beetles, are best known for their damage to green and unseasoned lumber. They inhabit the trunks branches of pecan and hickory as well as many ot deciduous trees (Baker 1972, Bright 1968). *Xyleborus* spp. are widely distributed from Can throughout the eastern half of the United Sta *Platypus compositus* is found from Mexico through the Southern United States northward to West gina. Ambrosia beetles seldom attack healthy, vig- ous trees; their attacks are largely limited to stre trees weakened from drought, disease, old age, in defoliation, wounding, and other factors that proc tree stress. Thus, when trees are successfully attac by ambrosia beetles, one can be sure that the t have been under stress of some sort. The beetles nel through the bark directly into the sapwood sometimes even into the heartwood, especi *P. compositus*. Although ambrosia beetles are not killers, the physical wounds produced by large n bers of beetles provide ports of entry for dis agents that may cause tree death. The pinholes associated stain quickly degrade the wood for lur and other wood products.

Description.—Adults of the *Xyleborus* spp. small, brown, reddish-brown, or black elon beetles with compact cylindrical bodies that vary 1.5 to 3.0 mm in length (Bright 1968, Chamb 1939, Blackman 1922). The adults of *P. compo* can be distinguished by having longer and more der bodies and wide heads flattened in front (fig. The first segment of the tarsus is as long as al other tarsal segments combined and about 4.5 m length. The eggs are elongate oval and pearly w The larvae of *Xyleborus* spp. are C-shaped, leg white to cream colored, and reach 3 to 4 mm in le larvae of *P. compositus* (fig. 30B) are straight to slightly C-shaped, legless, white to cream colored reach 5 to 6 mm in length.

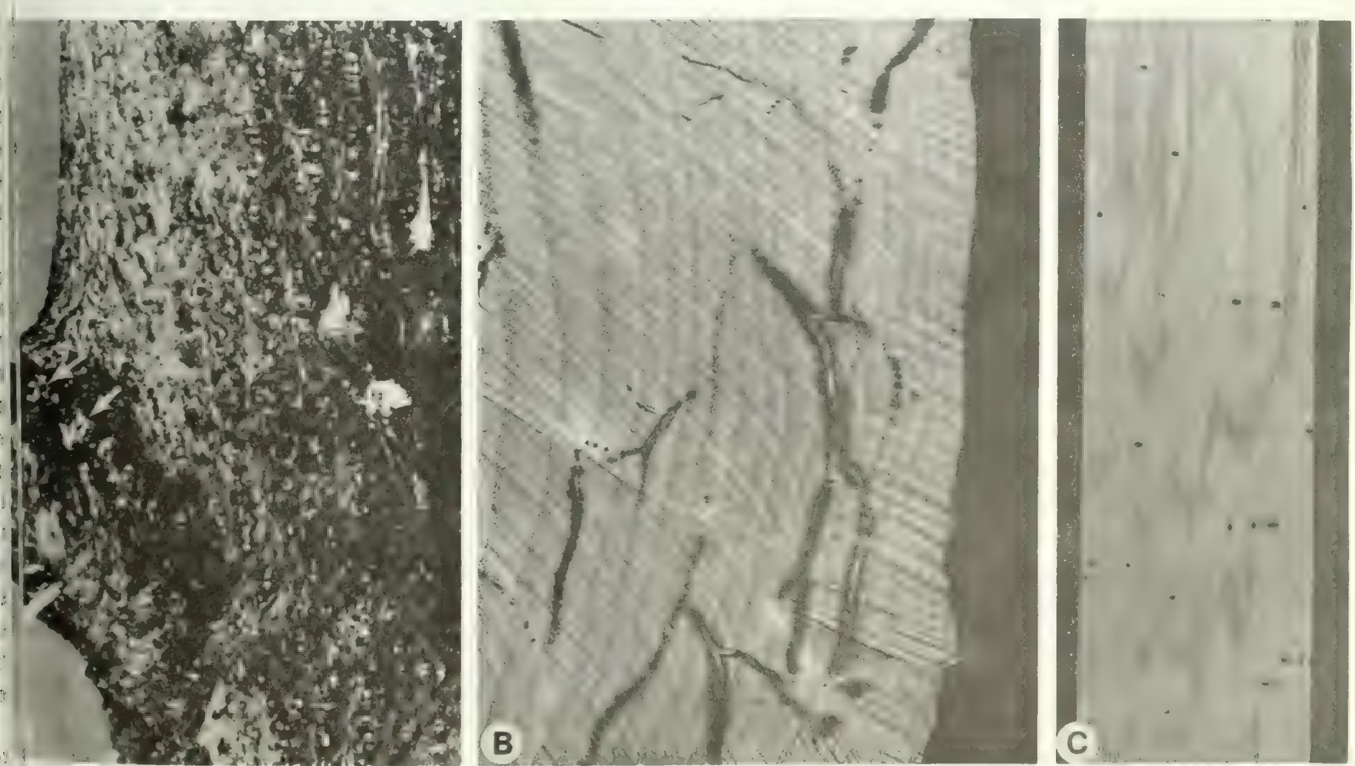
Evidence of Infestation.—Infested trees are us attacked by numerous beetles that bore many form, round (0.8- to 1.7-mm diameter) holes di



igure 30.—*Life stages of* Platypus compositus: *(A) adult beetle; (B) nearly mature larva.*

rough the bark into the wood (Chamberlin 1939). s the beetles construct their galleries, they push the brous (*P. compositus*) or granular (*Xyleborus* spp.) oring dust to the outside through the entrance holes ig. 31A). The boring dust is usually in evidence on e bark just below the entrance holes or in loose piles the base of the tree; during humid weather it may ick together as it is pushed out to form string-like asses. Sap frequently oozes from many of the en- ance holes, staining the bark around and below the trances. Active galleries are kept free of boring dust d are light colored; vacated galleries are stained ack by fungi. The galleries extend directly into the pwood and then branch several times—the branch- g pattern depending on the species (fig. 31B). These lleries cause dark-stained pinholes that will show up as defects in sawn lumber (fig. 31C).

Biology.—In the deep South the beetles are active most of the year, but further north they hibernate in brood galleries in the host tree (Chamberlin 1939). In the spring the adults emerge and initiate new attacks on the same tree or on different trees. Both adults and larvae feed on moldlike fungi that they culture in the galleries. The insects carry the specific inoculum from one tree to another and grow the fungi in pure culture on the walls of the tunnels. Galleries 0.8 to 1.6 mm in diameter are bored horizontally into the sapwood, then branch several times for a distance of 10 to 40 cm. Galleries of *P. compositus* are much more extensive and extend deeper into sapwood and heartwood than those of *Xyleborus* spp. Females deposit eggs in loose clusters in the galleries and may lay up to 200 eggs each. The eggs hatch in 6 to 10 days, and the young larvae wander freely about the mines and feed on the ambrosia fungus. Several adults may occupy each gallery. Both adults and larvae help to excavate and extend the galleries. When full-grown, the larvae of *P. compositus* excavate cells along the main gallery in which they transform to pupae and adults; those of *Xyleborus* spp. pupate freely in the galleries without making cells. Development from egg to adult during the summer requires 5 to 8 weeks. There are several generations per year in the Gulf Coast States. Successive broods may continue to attack a tree as long as it remains suitable. Infested trees that die



ure 31.—*Evidence of infestation by* Xyleborus *and* Platypus *spp. in pecan: (A) fresh white frass at pinhole entrances in trunk; (B) black-stained branching galleries in sapwood; (C) pinhole defects in sawn lumber.*

become unsuitable for brood development as soon as the moisture content drops below about 48 percent.

Control.—Since ambrosia beetles rarely attack healthy vigorous trees, good cultural practices should be followed to promote and maintain tree vigor (Baker 1972, Payne and others 1979). Trees that are weakened or stressed apparently emit fermenting-like odors that attract ambrosia beetles. Because healthy trees do not emit these odors, they remain unattractive. Insecticides may be needed occasionally.

HICKORY BARK BEETLE

Scolytus quadrispinosus Say

Importance.—The hickory bark beetle, *Scolytus quadrispinosus* Say, is a pest of pecan and hickory and reportedly butternut and black walnut (McDaniel 1933, Goeden and Norris 1964). However, it shows a strong preference for the hickories and is reported to be the most important pest of this group of trees (McDaniel 1933). It is found from Quebec southward throughout the eastern half of the United States to the Gulf Coast States and westward to Texas. Both adults and larvae produce galleries between the bark and wood of trunks and branches. When attacks are numerous, the galleries soon girdle the tree. Trees stressed and weakened from drought, fire, storm, disease, or other cause are most susceptible to attack. Vigorous trees are seldom attacked except when large beetle populations are produced from nearby brood material. Although heavy infestations usually kill the tree, light infestations may only girdle branches or a portion of the trunk, causing top dieback.

Description.—The adult is a short, 4- to 5-mm long, stout, thickly cylindrical, black to reddish-brown, almost hairless beetle (fig. 32A) (Goeden and Norris 1964, McDaniel 1933). There is a short curved spine or hook on the front tibia. The venter of the male is deeply excavated; the third abdominal segment is armed with three spines, the fourth with one large median spine. The venter of the female is without spines. The egg is ellipsoidal, cream colored, and barely visible to the naked eye. The larva is short, curved or slightly C-shaped, legless, yellowish whit and 5 to 8 mm in length when mature (fig. 32B). Th body appears wrinkled. The pupa is compact, fragil and white.

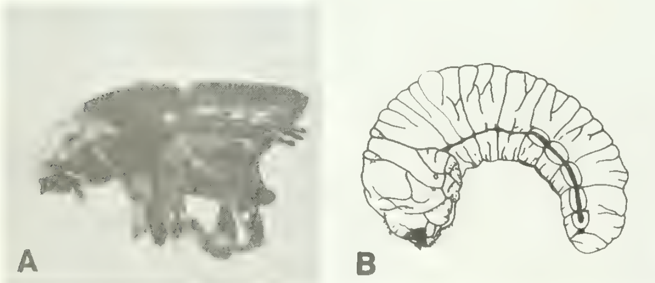


Figure 32.—*Life stages of* Scolytus quadrispinosus: *(A) adult beetle; (B) mature larva.*

Evidence of Infestation.—Damage occurs from fee ing in terminal growth and by tunneling in trun and large branches for breeding purposes (Blackma and Ellis 1915, Goeden and Norris 1965). Througho the summer months, newly emerged adults feed c twigs in the tree crown. Their short food tunnels a mainly confined to axillary buds and leaf bases in th current year's growth and the junctions of current a 1-year-old growth. Heavy twig feeding may cause ye lowing and premature dropping of leaves and broke twigs scattered throughout the crown, but this seldo seriously weakens the tree.

The most serious damage results from tunnelin and reproducing in the trunks (fig. 33). In the fall a winter after initial attack, the presence of numero round, 3-mm diameter entrance holes in the bark a often the only signs of attack. During winter a spring, woodpecker holes in the bark are good indic tors of infestation; in spring, sparse or yellowed f liage are signs of beetle attack. Dead or dying tre with bark perforated by numerous 3-mm holes fro which beetles have emerged also indicate the beetl presence along with galleries beneath and within t bark of such trees. The inner bark and wood surfac are engraved with peculiar centipede-shaped desig consisting of broad vertical galleries with narrow b

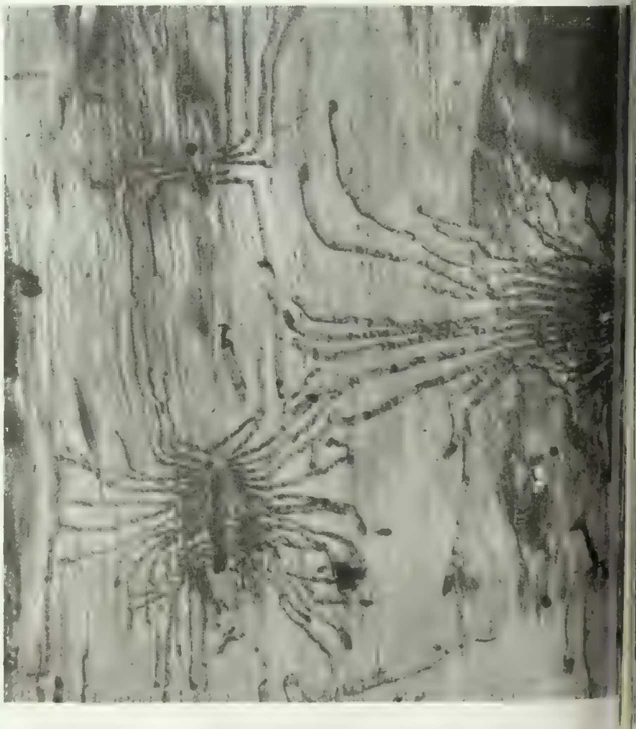


Figure 33.—*Galleries of* Scolytus quadrispinosus *beneath bar hickory. Note vertical egg gallery with larval galle radiating outward.*

ws radiating outward like centipede legs from eir side of them. The foliage of heavily infested trees ns red within a few weeks after attack and finally ns brown as the tree succumbs (fig. 34).

Biology.—The beetles overwinter as larvae in varis developmental instars (Goeden and Norris 1964, 65, McDaniel 1933). During spring the oldest lare transform to pupae in elliptical chambers termiting each larval tunnel just beneath the bark sure. Beetles emerge from May through late August. e beetle population and seasonal activity reach a ximum during July and early August. The newly erged beetles fly to the crowns of host trees and d mainly in terminal and twig growth for 10 to 15 s. Sexually mature beetles are then attracted to -vigor trees where they bore into the trunks and nches for breeding purposes. Here the females exate short (12 to 50-mm) vertical egg galleries been the bark and wood. Mating and egg laying conue throughout the summer, with each female positing 20 to 60 eggs singly in small niches along her side of the egg gallery. Each egg is covered with lug of macerated frass. The eggs hatch in 10 to 12 s. The larvae mine at right angles to the main llery and parallel to each other, but as the larvae ome larger their galleries diverge more and more, resembling an engraving of "centipede legs." Larval mines extend 76 mm or more away from the egg gallery, severing the trees' food and water conducting tissues. Mature larvae leave the cambium and bore into the outer bark where they construct pupation cells. There is one generation per year in the northern range and two per year in the southern distribution.

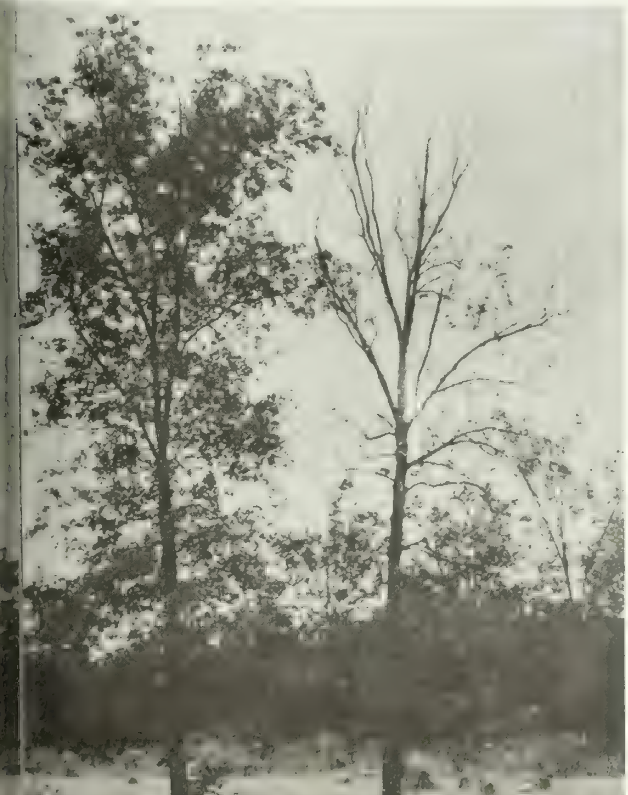


Figure 34.—*Hickory (right) dying from* Scolytus quadrispinosus *attack.*

Control.—Since hickory bark beetles rarely attack healthy trees, good cultural practices such as thinning, pruning, fertilization, and irrigation are important for promoting and maintaining good tree vigor (Goedon and Norris 1964, Hopkins 1912). The most effective means of controlling a hickory bark beetle infestation is by destroying trees in which larvae are overwintering. Infested trees should be cut and burned or submerged in water, have the bark peeled, or be sprayed with an insecticide before beetle emergence begins in May or June. To protect high-value trees, thoroughly spraying the trunks and large branches with an insecticide during early July will curtail most breeding attacks.

RED-SHOULDERED SHOTHOLE BORER

Xylobiops basilaris (Say)

APPLE TWIG BORER

Amphiceris bicaudatus (Say)

Importance.—The red-shouldered shothole borer, *Xylobiops basilaris* (Say), and apple twig borer, *Amphiceris bicaudatus* (Say), are found throughout the United States east of the Rocky Mountains and in southern Canada (Baker 1972, Gill 1924, Moznette and others 1931). Pecan and hickory are among their favored hosts, but they also attack several other deciduous hosts. They generally attack severely stressed and dying or recently dead trees. Trunks of healthy trees growing in close proximity to heavily infested trees are occasionally attacked but seldom with success; however, *A. bicaudatus* may tunnel the twigs and small branches causing them to wither and die back. Although these borers may cause some twig dieback and possibly hasten the death of trees already stressed or dying from other causes, the threat to healthy living trees is minimal.

Description.—The adults of *X. basilaris* are 3 to 5 mm long, black, and bullet-shaped, with many small punctures over the body. The basal part of the elytra is dull reddish or yellow—hence the name "red-shouldered." The wing covers end in an oblique angle at the posterior end, the edges of which are armed with three conspicuous teeth on each side. The adults of *A. bicaudatus* (fig. 35A) are similar to *X. basilaris* except they are larger, range from 6 to 11 mm long, are dark brown, and lack the reddish marking on the wing covers. The larvae of both species are white and

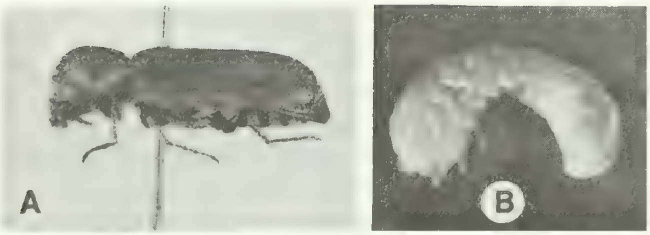


Figure 35.—*Life stages of* Amphiceris bicaudatus: *(A) adult beetle; (B) mature C-shaped larva.*

C-shaped; when full-grown, *X. basilaris* is about 5 to 6 mm long and *A. bicaudatus* is 6 to 12 mm long (fig. 35B). The head of the larva is globular and greatly enlarged into the prothorax, the mouthparts extend forward, and there are three pairs of thoracic prolegs.

Evidence of Infestation.—The adults of *X. basilaris* make small round exit holes 2 to 3 mm in diameter; the holes of *A. bicaudatus* are 3 to 4 mm in diameter and generally much less numerous (Payne and others 1979, Baker 1972, Gill 1924). The holes give a tree trunk the appearance of having been hit by birdshot, hence these borers are often referred to as "shothole" borers (fig. 36A). Light sawdust particles may be observed coming from the holes. The borings or frass the larvae are very fine and powderlike in appea ance; they are firmly packed or compressed within th galleries, which run parallel with the grain of th wood (fig. 36B). Trees cut back so severely that th trunk becomes saturated with sap are susceptible infestation by *X. basilaris*. Twigs that have wither and brown leaves usually contain single, round e trance holes 2 to 4 mm in diameter adjacent to a b or leaf base (fig. 36C). Dissection of the twigs usual reveals a hollow twig that is often occupied by a sing adult beetle from late fall to late spring.

Biology.—Adults emerge during the summer a fly in search of suitable host trees where they bo through the bark and into the sapwood (Gill 192 Lugger 1899, Baker 1972, Dean 1920). Tunnels a constructed across the grain just under the wood su face in the sapwood. These tunnels may complete girdle small-diameter limbs and trunks (fig. 36 Eggs are deposited at intervals along the sides of t tunnel. The larvae feed mostly in the sapwood and some extent in the heartwood. Larval mines run pa allel with the grain and are packed with fine, whi powderlike dust. Feeding may continue until t wood is quite dry. The winter is spent mostly as m

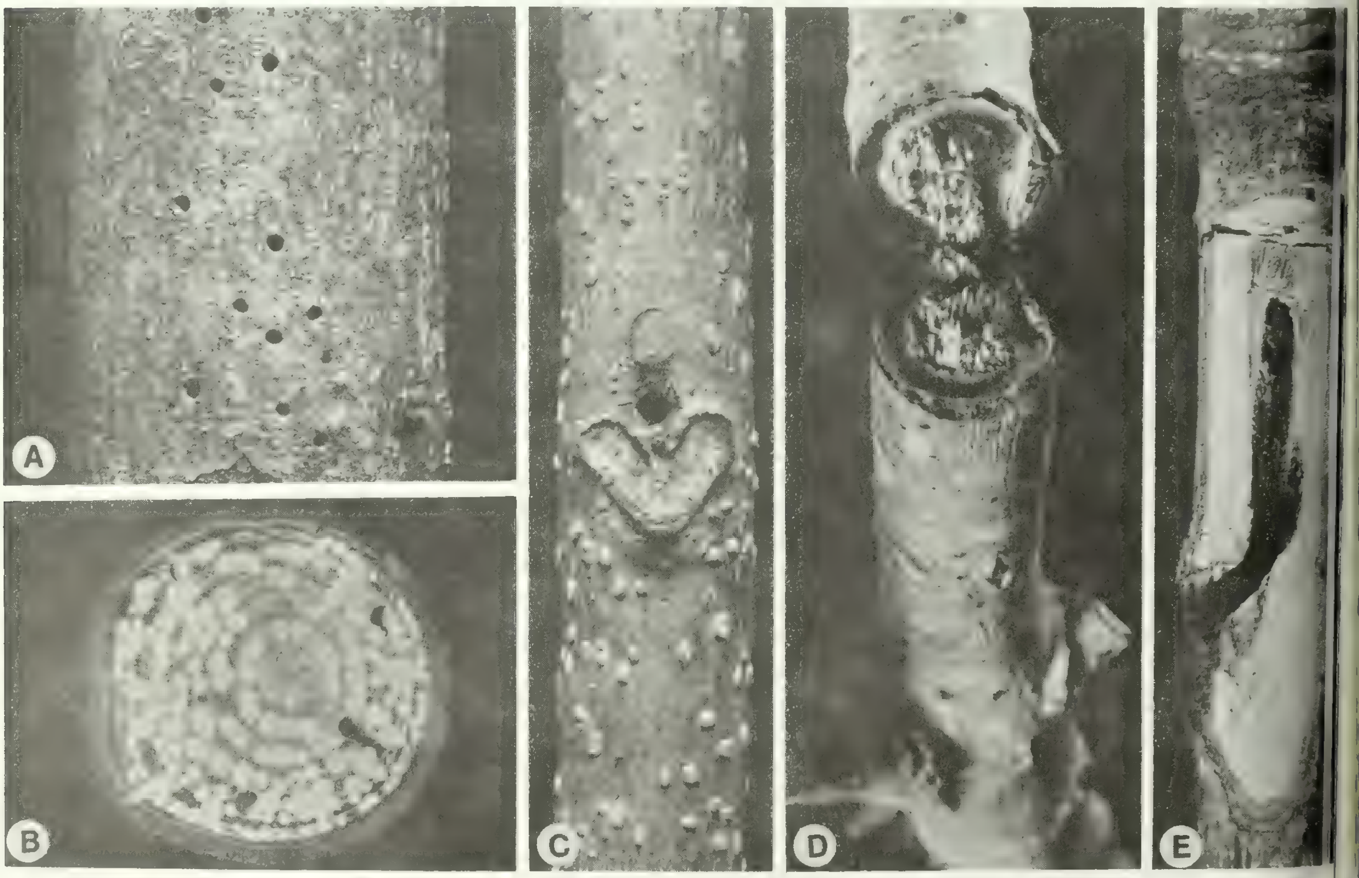


Figure 36.—*Habits and signs of attack by* Xylobiops basilaris *and* Amphiceris bicaudatus *in pecan: (A) exit holes (shotholes) in b (B) cross-section of stem showing ends of frass-packed larval galleries; (C) adult entrance hole between leaf scar and (D) girdling tunnel made just beneath bark by adult beetle; (E) overwintering gallery made by adult of* Amphiceris bicauda

e larvae in mines; larvae pupate and emerge as
ults the following spring and summer through cir-
ar holes cut in the bark. Adults of *A. bicaudatus*
en bore into twigs for food and shelter and com-
nly spend the fall, winter, and spring in galleries
hin the twigs (fig. 36E). A generation can develop
m egg to adult in 1 year under optimum conditions,
longer periods of time are sometimes required.

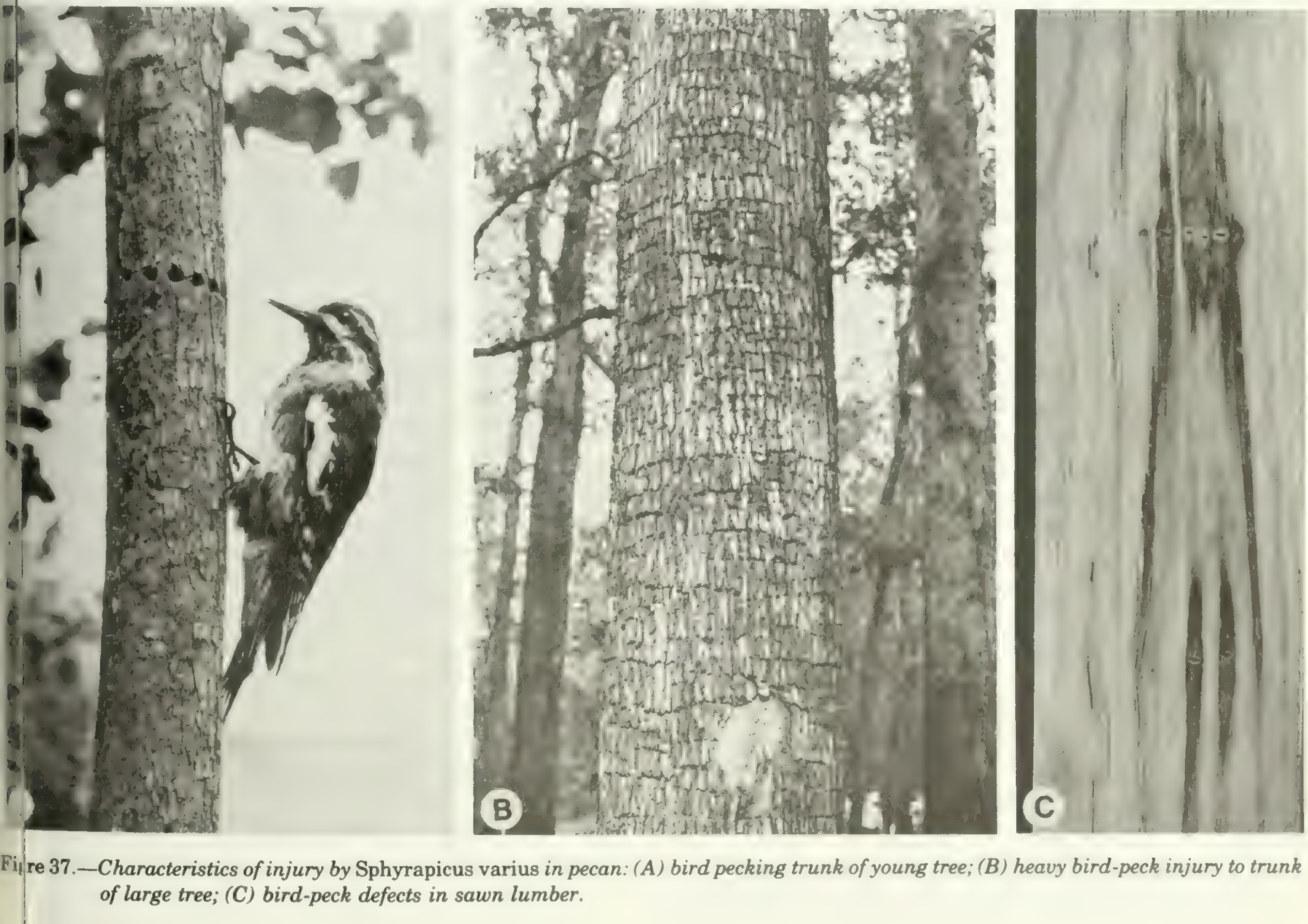
ontrol.—These borers present little threat to
lthy well-kept trees; therefore, good cultural prac-
es should be followed to maintain tree vigor (Dean
20, Moznette and others 1931). Sources of infesta-
n can be eliminated by promptly removing and de-
ying all dead and dying twigs and branches, prun-
s, and dead trees.

YELLOW-BELLIED SAPSUCKER

Sphyrapicus varius L.

mportance.—The yellow-bellied sapsucker, *Sphy-*
icus varius L., pecks small holes in tree bark, caus-
injuries that are often mistaken for insect
ers—hence its coverage in this paper. This pest is
ond over most of the United States and southern
ada, but its damage is best known in the Eastern United States. It attacks pecan and hickory as well as over 250 other trees and shrubs (Beal and McAtee 1922). As portions of the bark and cambium are removed by numerous pecked holes, the vitality of the tree is lowered. When the injury is extensive, individual branches or the entire tree may be completely ringed or girdled and killed. Sapsucker pecking disfigures ornamental trees and gives rise to holes, to sap spots, and subsequently to gnarled bark deformities that ruin the aesthetic appearance of the trees. Disease and wood-boring insects often become established at sapsucker wounds. The greatest damage done by sapsuckers, however, is to cause defects in the wood of trees cut for lumber, veneer, and handle stock. Economic losses to the lumber industry in hickory alone have been estimated at 1.2 million dollars annually (Dale and Krefting 1966).

Description.—The yellow-bellied sapsucker is a member of the woodpecker family (Picidae) and resembles the woodpeckers in appearance (fig. 37A). However, its habits are detrimental as opposed to the generally beneficial habits of woodpeckers. The identifying field markings of adult birds are a black crescent on the breast, pale yellow belly, longitudinal white stripe on the mostly black wings, and crimson



Fi re 37.—*Characteristics of injury by* Sphyrapicus varius *in pecan: (A) bird pecking trunk of young tree; (B) heavy bird-peck injury to trunk of large tree; (C) bird-peck defects in sawn lumber.*

red crown (Peterson 1947, Ostry and Nicholls 1976). Although it most closely resembles the hairy and downy woodpeckers and is between the two in size, it is the only woodpecker with a red forehead in combination with a black patch on the breast. In addition, the male has a crimson chin and throat that distinguish him from the female whose chin and throat are white.

Evidence of Infestation.—The yellow-bellied sapsucker pecks a series of small holes about 5 mm in diameter in the bark (Beal and McAtee 1952). Generally, the holes are made in horizontal rings (full or partial) around the trunk or branches (fig. 37B). The holes extend through the bark to the cambium, sometimes penetrating the sapwood to a depth of 3 mm. Occasionally the holes in a series are gradually enlarged until they girdle or partially girdle the stem. Dissections of trees that have suffered from repeated yearly attacks reveal characteristic symptoms of previous damage by sapsuckers. The evidence consists of uniformly spaced peck-marks surrounded by dark vertical stains, often with small pockets of ingrown bark and decay. These defects degrade the lumber sawn from damaged trees (fig. 37C). Attacks may be seen at any point on the trunk and branches but are perhaps most common on the bole area just below the lower branches. Small trees are particularly susceptible to attack.

Biology.—Although the yellow-bellied sapsucker is a member of the woodpecker family, it has a short brush tongue in contrast to that of true woodpeckers, which have long tongues equipped with barbed tips for preying upon wood-boring grubs. The sapsucker's staple diet is the living cambium layer, inner bark, and sap that flows from the pecked wounds (Dale and Krefting 1966). After settling in a locality, each bird pecks many trees but then selects a few trees for most of its feeding. Pecked holes are revisited several times daily to drink sap oozing from the wounds and to eat small insects attracted to the sap. On favored trees, holes are often enlarged as the sapsucker feeds on the cambium to freshen the wound and to stimulate sap flow. The yellow-bellied sapsucker is a migratory bird that spends its summers and nests primarily in the Northern States and southern Canada (Peterson 1947). In the fall it migrates southward, sometimes as far as the Gulf Coast.

Control.—Control is difficult, but several remedies have been used with some success on high-value trees (Ostry and Nicholls 1976, Beal and McAtee 1922). Trunks of individual trees may be wrapped with burlap or some other material to prevent attacks. Painting damaged trees with tree-wound paint will sometimes discourage the birds. Commercially available repellents have been used successfully in repelling sapsuckers. Spraying the trunk periodically with a soap solution has also helped to discourage attacks. Often only a single bird is responsible damage to a shade or ornamental tree; thus, if it be discouraged or eliminated, the problem is sol

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Appendix—Common and Scientific Names

CLASS: INSECTA

Lepidoptera
  Cossidae
    Pecan carpenterworm, *Cossula magnifica* (Strecker)
  Sesiidae
    Dogwood borer, *Synanthedon scitula* (Harris)
  Pyralidae
    American plum borer, *Euzophera semifuneralis* (Walker)
    Acrobasis shoot borers, *Acrobasis* spp.
Coleoptera
  Curculionidae
    Hickory shoot curculio, *Conotrachelus aratus* (Germar)
  Cerambycidae
    Hickory borer, *Goes pulcher* (Haldeman)
    Broadnecked root borer, *Prionus laticollis* (L.)
    Tilehorned prionus, *Prionus imbricornis* (Drury)
    Twig girdler, *Oncideres cingulata* (Say)
    Twig pruner, *Elaphidionoides villosus* (F.)
    Oak twig pruner, *Elaphidionoides parallelus* Newman
    Branch pruner, *Psyrassa unicolor* (Randall)
  Buprestidae
    Hickory spiral borer, *Agrilus arcuatus* Say
    Flatheaded appletree borer, *Chrysobothris femorata* (Olivier)
  Platypodidae
    Pin-hole borer, *Platypus compositus* (Say)
  Scolytidae
    Pin-hole borers, *Xyleborus* spp.
    Hickory bark beetle, *Scolytus quadrispinosus* Say
  Bostrichidae
    Red-shouldered shothole borer, *Xylobiops basilaris* (Say)
    Apple twig borer, *Amphiceris bicaudatus* (Say)

CLASS: AVES

Piciformis
  Picidae
    Yellow-bellied sapsucker, *Sphyrapicus varius* L.

Solomon, J. D.; Payne, J. A. A guide to the insect borers, pruners, and girdlers of pecan and hickory. Gen. Tech. Rep. SO-64. New Orleans, LA: U.S. Department of Agriculture, Forest Service. Southern Forest Experiment Station; 1986. 31 p.

The importance, identification, biology and indirect control of insects attacking shoots, branches, trunks, and roots of trees are presented. Damage due to and control of the yellow-bellied sapsucker is discussed.

Additional keywords: *Carya*, impact, identification, pests, control, bird damage, yellow-bellied sapsucker.

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Managing Southern Forests for Wildlife and Fish

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MANAGING SOUTHERN FORESTS FOR WILDLIFE AND FISH

A PROCEEDINGS

EDITED BY JAMES G. DICKSON AND O. EUGENE MAUGHAN

Preface

Southern forests are very productive for wildlife as well as wood fiber. User recreation demands for game and nongame wildlife and fish continue to increase as human populations grow in the sunbelt. The main determinant of wildlife populations is suitability of forest habitat and the primary manipulator of the habitat is the forester. Forestry decisions and practices determine habitat suitability for wildlife communities and ultimately wildlife populations. With this publication we plan to demonstrate how southern forests can be managed for the myriad of wildlife species. General topics in the publication relating to wildlife communities include economics of accommodating wildlife and fish, impact of specific forestry practices, special techniques, agency policy and practices, and prospects for the future. Although earlier drafts of these papers were edited, the content of each final manuscript was the responsibility of each author. We thank Ronald Thill, Alexander Zale, Hugh Black, Lowell Halls, Roger Baker, George Hurst, and James Neal for assistance in reviewing these manuscripts. This publication is from the proceedings of the Wildlife and Fish Ecology Technical Session, 1986 Society of American Foresters National Convention, Birmingham, Alabama.

James G. Dickson
O. Eugene Maughan, editors

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Introduction

Thomas H. Ellis

It is a pleasure for me to introduce the 1986 technical session of the Working Group on Wildlife and Fish Ecology. The title of this technical session, "Managing Southern Forests for Wildlife and Fish," is an intriguing one. It incorporates elements of a basic fact, of a general area of professional controversy, and of an ever-increasing public interest. It is a fact that southern forests, under almost any sort of forestry program, are major producers of wildlife and the sources of a huge proportion of all the fresh water supplying southern streams and lakes. Nothing short of wholesale conversion to agriculture could alter this situation significantly.

The disputes between foresters, wildlife professionals, and water resource managers over relative priorities among timber, wildlife and water are legendary and intensely frustrating to all sides. Public sentiment seems generally favorable toward trees, animals and fish of all sorts, is largely uniformed and appears to increase in passion as wealth and education and urbanization of the human population grow. Further, the spectrum of groups who have legitimate interests in forests, water and wildlife grows more and more varied every year.

In this situation, one would hope that there would be grounds for common cause among the natural resource professions, and with environmental interest groups, toward public and private policies that would best serve the long-run interests of our region. Technical information, from experts such as the members of this working group, is essential to the search for such policies.

The South presents particularly important opportunities for alliances among natural resources professions for several reasons. First, the nature and history of southern forests typically have not led to as sharp conflicts between foresters and other professions as occur regularly in the West. Most of our forest acreage here is privately owned and has been logged repeatedly in the past 100 years. We have little virgin forest to draw arguments over preservation. And, until recently, Southerners have enjoyed less wealth and education than people in other regions and been less disposed towards environmental concerns.

Second, demographic statistics and the newspapers make it clear that the situation in the South is changing. The southern states are increasing dramatically in population, educational levels and wealth. The influences of urban populations more and more are noticed in state legislatures, in local land use restrictions, and in recreational uses of public and private lands. Although there still are large areas of the South where foresters, especially on private lands, have little interference from environmen concerns, we appear destined to suffer the same kinds of frustrations that our western colleagu have--unless we have the foresight to anticipat the most important issues and take action on th now.

Land use shifts between agriculture and fo estry in the South are commonplace and there is enormous potential in either direction. The environmental benefits of timber management as compared to farming, mining, and real estate development seem so great that there should be fundamental case for foresters to seek support commercial forestry from groups which often oppose it.

The least effective strategy for foresters would be to write off complaints from other professions or interest groups as unimportant. In my view, the most useful approach is for foresters to demonstrate a strong concern for the environment, to seek effective ties with other natural resource professions and environmental organizations, and to marshal good information on the influences of timber management on wildlife, fish, and other resources.

Research on the environmental influences o timber management has been going on for years i the South, with some excellent results. Exampl include comprehensive work on white-tailed deer a great deal of information on quail and turkey habitat requirements, and extensive research on effects of harvesting on mountain watersheds. contrast, we have not much data relating forest and most non-game animals (which now may occasi more serious controversy than game species) or forestry and water management in the coastal plains. In many instances, we have case studie for a particular locale but inadequate information for regional issues. We particularly lack quantitative functions which would predict the levels of output for other resources in relatio to changes in timber production. This is a ver tough challenge but one we must meet in order t avoid or meet court challenges and to hold the public's confidence.

Today's working group session brings together speakers with outstanding credentials fo viewing many aspects of our topic--Managing Southern Forests for Wildlife and Fish. Some o them are researchers; others are people with immediate responsibility for reconciling land management issues. All are people who are deal with questions of great, long-run importance fo southern forestry.

Thomas H. Ellis, Director, USDA Forest Service, Southern Forest Experiment Station, New Orleans, LA

Economics of Accommodating Wildlife

C. William McKee

Abstract.--Revenues generated from timber production alone are compared with joint timber-wildlife production. Net revenues from joint timber-wildlife production exceed revenues from timber alone. The increased revenue should provide added incentive for forest landowners, particularly nonindustrial landowners, to practice better forest management.

INTRODUCTION

In recent years, intensive forest management s received considerable attention from sports-n and concerned conservationists. Some contend at converting large areas of mixed pine-hardwood ands to intensively managed short-rotation pine antations will adversely affect wildlife popula-ons. Others contend that age-class distribution pine stands, streamside management zones (Section 8, Public Law 92-500), prescribed burning and inning will increase habitat diversity and, thus, hance certain wildlife populations. In other rds, the quality of forest wildlife habitat pends upon the type of timber management practiced (alls, 1975).

In the past, forest managers have been led to believe that adopting wildlife habitat enhancement guidelines will have an adverse effect on the business' basic objective of maximizing profit. The industrial forest manager has been forced to make decisions oriented toward maximizing profits because tradition has led him to believe that wildlife habitat enhancement can only be achieved at the expense of timber production. More recently, forest management strategies have been adjusted to accommodate increasing demands for all forest resources.

The purpose of this paper will be to identify the economic problems and constraints associated with the assessment of wildlife habitat tradeoffs and to determine the impact of habitat enhancement on dollar returns of a typical forest management strategy.

ECONOMIC PROBLEMS AND CONSTRAINTS

Market value is the commonplace and common sense approach to setting values in our democratic society. We experience it daily everytime we make an exchange in the market place as a willing buyer with a willing seller or vice versa. Such exchanges represent most of the goods and services we acquire or provide for others. Where markets do not exist, as is the case with wildlife and other recreational activities, a proxy for market product dollar returns must be developed. Many studies discuss comparing non-market products with marketable products (Bockstael and McConnell 1978, Gibbs 1975, Martin et.al. 1974).

One technique involves assessment of investment in terms of opportunity costs. For example, if timber is produced jointly with recreation or hunting opportunities, revenues from timber normally decline. The reduction of revenues from timber is considered an opportunity cost in that income must be foregone in order to accommodate other outputs. Loss of timber revenue then becomes an estimate of value for the non-timber outputs. The opportunity cost approach will be used to assess timber-wildlife habitat tradeoffs in this paper.

ANALYTICAL METHODS AND ASSUMTIONS

Discounting Models

Various methods are used to estimate the profitability of a timber production investment. The most acceptable method, however, for appraising long-term projects such as forestry is discounted cash flow or present net worth (PNW) analysis (Gunter and Haney 1984). The superiority of the technique, and the characteristic which distinguishes it from others, is its recognition that money has a time value. PNW calculations give us a dollar figure which tells how much our forestry investment will return. A positive PNW tells us that our investment will return more than the interest rate we choose for discounting--say 12%.

Another economic indicator which is based on PNW is annual equivalent. It automatically adjusts a timber investment, regardless of rotation length, to a one-year equivalent. Annual equivalent thus provides a convenient way of comparing a timber

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C. William McKee, Forest Economist, School of Forestry, Auburn University, Alabama 36849 enterprise with shorter-term uses of the land such as cropping or recreations.

Assumptions

To assess economic returns for a typical forest management strategy, we must make assumptions concerning discount rates, expected costs, timber yields, and stumpage prices.

Discount rates for the analysis were set at 6% in constant or real dollars. A 6% real, or constant dollar, discount rate translates to a 10% nominal or market rate if inflation is 4%.

Investors in timber growing may have to buy land; prepare planting sites; plant, release, thin, protect, and prune trees; prepare and administer timber sales; install hardwood leave strips (Streamside management zones); and pay annual taxes. Not every timber grower will have all of these expenses, but all will have some costs in growing timber. Such costs can be thought of as investments that must be made to grow a certain kind of timber in a certain way. Expected costs for this analysis are presented in Table 1.

Before timber sale incomes can be derived an estimate of what kind and how much timber will be available for sale throughout the rotation must be determined. Loblolly pine yields for average site (SI_{25}60) land are presented in Table 2 (Hepp 1985). 'PW' and 'ST' denote pulpwood harvested in cords per hectare and sawtimber harvested in thousand board feet Scribner per hectare, respectively.

Table 1.--Direct costs of intensive forest management for timber production only and joint timber-wildlife production[a]

Year	Timber only	Timber and wildlife	Today's cost ($/ha)	
1	Site Prepare	Site Prepare	222.39	(90)
1		SMZ installation [b]	14.83	(6)
2	Plant	Plant	135.91	(55)
8		Precommercial thinning	111.20	(45)
8 to 35 3 year intervals		Prescribe burn	19.77	(8)
12 to 35, 5 year intervals	Prescribe burn		19.77	(8)
Annual	Management costs	Management costs	12.36	(5)
Annual	Taxes	Taxes	3.71	(1.50)

[a] Per acre values are in parentheses.
[b] 6.5 hectacre (16 acre) Streamside Management Zone.

Table 2.--Per hectare loblolly pine yields for timber production only and joint timber-wildlife production[a]

Management Regime	1st Thinning			2nd Thinning				Harvest		
	Age	RBA[c]	PW	Age	RBA	PW	ST	AGE	PW	ST
Timber	15	198 (80)	30.6 (12.4)	25	198 (80)	23.5 (9.5)	3.9 (1.6)	35	32.9 (13.3)	21.1 (8.6)
Timber & Wildlife[b]	15	148 (60)	19.8 (8.0)	25	148 (60)	16.1 (6.5)	6.7 (2.7)	35	15.1 (6.1)	22.0 (8.9)

[a] Per acre yields are in parentheses.
[b] Precommercial thinning at age 8, residual component of 350 stems per acre.
[c] 'RBA' denotes residual basal area in square feet per hectare.

The last assumption needed to assess economic returns is stumpage price. Stumpage prices used are based on the average price reported, 1980-1986, in Timber-Mart South for Alabama (Table 3). No real price increase in pulpwood or sawtimber stumpage is assumed.

Table 3.--Average stumpage price for various forest products, Alabama, 1980-1986

	Pulpwood	Sawtimber
	($/cord)	(S/MBF, Sc)
High	20	166
Medium	16	149
Low	12	116

APPLICATIONS AND RESULTS

For our purpose, we want to establish maximum financial returns as the goal of our forest manager. With this as our objective, an assessment was made for managing a 65 hectare (160 acre) tract for timber only and joint timber-wildlife production. The management strategy and expected yields have been presented (Tables 1 and 2). To enhance diversity, however, ten percent of the 65 hectares (16 acres) is assumed to be managed as a streamside management zone under the joint timber-wildlife option. The streamside management zone will be managed for production of high quality hardwood saw-timber. Periodic harvests will be made every ten years.

Economic returns for our two management options - 1) timber production only versus 2) joint timber-wildlife production are found in Table 4. Present net worth and annual equivalent values indicate that there is an opportunity cost associated with managing for both timber and wildlife. The timber revenue foregone column of Table 4 represents the opportunity cost of the amount of timber revenue that must be sacrificed to accommodate wildlife habitat enhancement.

Table 4.--Opportunity cost of providing improved wildlife habitat[a/]

Stumpage Option	Management Regime	Present Net Worth	Annual Equivalent	Timber Revenue Foregone
		($/ha)	---------------------($/ha/year)---	
High	Timber Only	433.14 (175.29	29.87 (12.09)	12.23 (4.95)
	Timber & Wildlife	256.04 (103.62)	17.64 (7.14)	
Medium	Timber Only	280.36 (113.46)	19.35 (7.83)	10.72 (4.34)
	Timber & Wildlife	125.18 (50.66)	8.62 (3.49)	
Low	Timber Only	57.55 (23.29)	3.98 (1.61)	8.70 (3.52)
	Timber & Wildlife	-68.32 (-27.65)	-4.72 (-1.91)	

[a/] Per acre values are in parentheses.

A variety of options are available in forest management. Landowner objectives determine how forest holdings are managed. If the landowners objective is joint timber-wildlife production, loss of timber revenue can be offset by leasing hunting rights. What is an appropriate lease fee? Landowners will not incur a loss for increasing their management efforts if they charge leasees $8.70 to $12.23 per hectare per year ($3.52 to $4.95 per acre per year). Results of a telephone survey of Alabama forest industry and large landowners revealed that current hunting leases range from $2.47 to $51.89 per hectare per year ($1 to $21 per acre per year) with an average beginning $12.36 per hectare per year ($5 per acre per year). Hunting lease fees are extremely sensitive to management services provided by the landowner and to population levels of the preferred game specie. For the moment, assume that the landowner can lease his land for $12.36 per hectare per year. This fee will buy the leasee the type of wildlife habitat provided by the joint timber-wildlife management strategy identified in Table 1.

Compared to the timber only strategy, a $12.36 per hectare per year lease fee will increase landowner revenue by $0.99 to $4.52 per hectare per year ($0.40 to $1.83 per acre per year) (Table 5).

DISCUSSION

The most apparent conclusion from Table 5 is that net revenues from timber-wildlife management strategies exceed profits from timber alone. This is of particular significance for non-industrial landowners since it gives them the opportunity to earn annual income from hunting.

Table 5.--Joint timber-wildlife economic returns for an annual lease rate of $12.36 per hectare per year[a/]

Stumpage Option	Present Net Worth	Annual Equivalent	Revenue Gain Timber Only
	($/ha)	---------$ per hectare	
High	447.52 (181.11)	30.86 (12.49)	0.99 (0.40
Medium	316.53 (128.14)	21.84 (8.84)	2.50 (1.01
Low	123.13 (49.83)	8.50 (3.44)	4.52 (1.83

[a/] Per acre values are in parentheses

The added income partially offsets a major drawback of timber investments for these owners namely, the long time period between initial expenditures and generation of revenues.

Owners of industrial forest land have a somewhat different perspective on their role in creating and maintaining wildlife habitat diversity. As Lewis (1983) notes, "Forest industry operates within a mixed market economy and owns forest land for one or more of three basic reasons. The first of these is to insure an adequate supply of raw material for processing plants. The second is to speculate on the increased value of both land and timber. The third is to earn a return from the biological growth on a forest property."

Diversity, a key component of wildlife hab ithin the intensively managed forest is the result f decisions relating to size, shape, and distribu-ion of pine plantations and the maintenance of ther habitat types in streamside management zones nd non-intensive management areas. Deviation rom a corporate/regional timber management trategy to enhance wildlife habitat diversity ncrease the firm's direct costs. Some examples nclude breadup of natural compartments into eparate units, and harvest and silvicultural reatments are not carried out at the optimum time. Kee (1983) estimates these direct costs to range rom $2.08 to $8.01 per hectare per year ($0.84 $3.24 per acre per year). On a per cubic foot sis this amounts to additional costs of $0.08 $0.32. Pine stumpage in Alabama is currently .55 per cubic foot. Consequently, the direct st of enhancing wildlife habitat amounts to 14 58 percent of the stumpage value. This is gnificant because it adds to investment cost thout increasing timber yield. Additional rect costs incurred by the firm include increased ad maintenance and fire protection, and control public access.

SUMMARY AND CONCLUSIONS

Managing for timber production only will ovide some habitat diversity. Enhancing wildlife bitat to a higher degree can only be achieved by tering silvicultural treatment and size, shape d distribution of management units. These tivities have a cost associated with them which n be measured by lost timber revenue.

Forests produce multiple outputs and are often naged on a multiple-use basis. Results from is analysis should help quantify the public lations cost associated with enhanced wildlife bitat.

Where joint timber-wildlife production is e goal, a careful analysis of market opportuni-es for lease hunting should be made. If the rkets are there, all indications suggest that nagement for joint production of timber and ldlife is more profitable than timber alone. e possibility of hunting lease income should ovide additional incentive to owners of forest nd, especially nonindustrial landowners.

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Some Economic Benefits of Protecting Water Quality

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and
Bennett Foster

Abstract: Often water quality management is viewed as a cost with no financial return for the investment, but protecting water quality for fisheries can have positive economic returns to the forest landowner. Many of the practices used to protect water quality are the same ones done to protect or improve soil productivity. Protecting or improving soil productivity means more timber produced per acre, which is translated into economic returns to the landowner. Also, erosion and sediment control practices can save in road construction and maintenance costs.

INTRODUCTION

Erosion produces sediment and sport fishery habitat is adversely affected by escessive sediment. Erosion control in forests can provide significant economic returns to landowners from increased timber production, savings in site preparation, road construction, and road maintenance costs.

In forest management, practices to reduce erosion are often the same ones needed to maintain or improve soil productivity. For example, to lower erosion, ground cover is increased by leaving litter and debris in place. Also, care is taken to decrease soil compaction and displacement. Reducing soil exposure, displacement, and compaction leads to maintaining or improving soil productivity, thus sustaining or increasing timber production. It is through maintaining or improving timber growth and yields that landowners and ultimately society benefit economically (Dissmeyer 1985).

SEDIMENT AND FISH HABITAT

Fine sediment has negative impacts on habitat for rainbow trout (salmo gairdneri), smallmouth bass (micropterus dolomieui), and largemouth bass (micropterus salmoides). Raleigh et. al. (1984) identifies two habitat factors for rainbow trout that are adversely affected by increasing amounts of sediment: predominant substrate type in riffle-run areas for food production and percent fines in riffle-run and spawning areas during average summer flows. Edwards et. al. (1983) reports that fine sediments affect smallmouth bass habitat suitability indexes for dominant substrate type within pool, backwater or shoal areas, and maximum monthly average turbidity level during the summer. Stuber et. al. (1982) identify maximum monthly average turbidity durin the growing season and substrate composition within riverine pools and backwaters or lacustrine littoral areas as factors that influence largemouth bass.

Stowell et. al. (1983) developed a model to predict sediment yield and fish populations for Forest Land Management Planning in the Idaho Batholith. The model was built using available research results and field data. The model was validated to give reasonable estimates of fish population responses to varying sediment yields from different management scenarios. The sediment yield model accounts for erosion from various sources, estimates how much of the erode material enters the stream network, and is transported to the stream segment where a fish response is approximated.

Stowell et. al. (1983) presents several habitat and fish response curves for sediment impacts. The percentage of fine sediment (particles in th channel that are less than 6.4mm in diameter) rises as the percent sediment yield over natural yield increases (Fig. 1). As sediment yield increases, embeddedness increases and the impact upon fish increases. Embeddedness is a rating o the degree the larger particle sizes (e.g., gravel, rubble, and boulder) are covered by fine sediment.

The model developed by Stowell et. al. (1983) translates fine sediment and embeddedness into estimates of percent fry emergence, summer rearing capacity, and winter carrying capacity for rainbow trout (Fig. 2). Fry emergence shows a precipitous drop between 20 and 30% fine sediment and is near zero at 40% fines. Figure 1 suggests that increasing sediment by 100% over natural yields will increase fine sediment in th streambed from 20 to 30%. A 180% increase in sediment yield would result in 40% fines.

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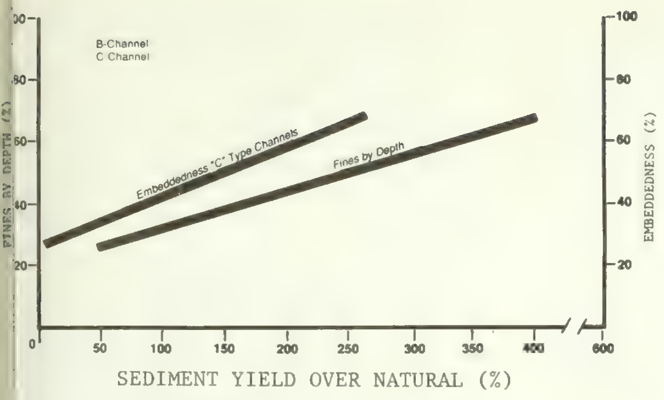
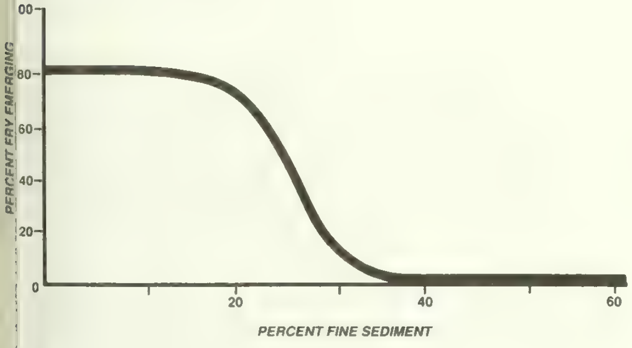


Figure 1 - Sediment yield over natural versus fines by depth response curve for "B" and "C" channels, and versus embeddedness. Clearwater and Nez Perce National Forest's data.



gure 2 - Fine sediment by depth versus alevin
ry) emergence response curve for rainbow steel-
ad trout.

r age zero rainbow trout, the summer rearing
pacity in runs decreases from 10 to 2 fish per
uare meter as embeddedness increases from 0 to
0% (Figs. 3A and 3B). Rearing capacity for
e-year old rainbow trout drops from approxi-
tely 3 to approximately .3 fish per square
ter. Similar results are seen with the impor-
nce of embeddedness on the winter carrying
pacity in pools for young rainbow trout (Fig.
.

e previous information has demonstrates the
nkage and importance of sediment yield to trout
production and the carrying capacity of
reams. The same principles apply to smallmouth
d largemouth bass. These relationships are
portant to the fisheries biologist and the
sherman, but forest landowners are more inter-
ted in erosion and sediment control as it
lates to returns on investments from their land.

ECONOMIC BENEFITS FROM SEDIMENT CONTROL

osion and sediment control for fisheries can
so provide significant economic returns to
ndowners. From increased timber production,
vings in site preparation, road construction,
d road maintenance costs. As mentioned earlier,
e practices used to reduce erosion and sediment

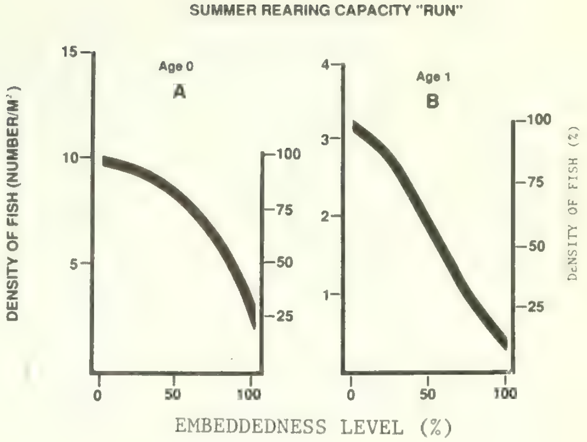


Figure 3 - Relationship between summer rearing capacity (density of fish in numbers of fish/m and as a percentage) and substrate embeddedness in runs from age 0 and 1 rainbow trout.

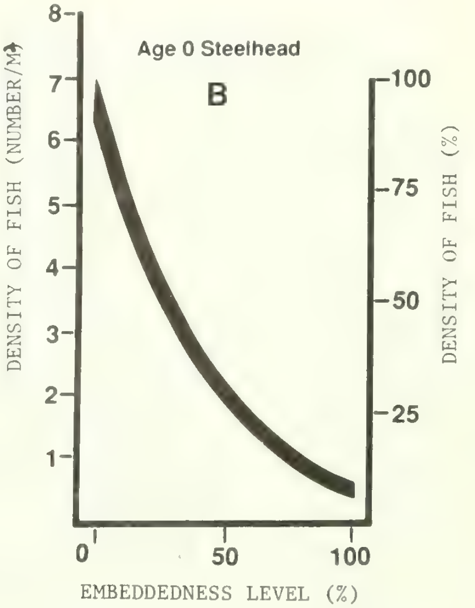


Figure 4 - Relationship between winter carrying capacity of pools (density of fish in numbers of fish/m and as a percentage) and subtract embeddedness for age 0 rainbow trout.

are often the same ones needed to maintain or improve soil productivity.

Dissmeyer (1985) has summarized the basic principles of soil productivity as follows:

1. Site productivity is a function of site location, soil productivity, species selection, management, and mortality. Soil productivity is one factor in the equation. If other factors are held constant, the impact of management on soil productivity can be determined.

2. Three key soil factors affect forest soil productivity: soil physical, chemi-

Table 1. Analysis of Two Management Schedules on Site Productivity

		Light Site Prep.		Heavy Site Prep.	
Year	Silviculture Treatment	Value Per Hectare (1984 $)	Wood M^3/ha	Value Per Hectare (1984 $)	Wood M^3/ha
1984	Site Prep./Tree Planting	$297		$420	
1999	Thinning	252	64.2 pulpwood	180	46.0 pulpwood
2010	Thinning	526	22.3 saw timber 33.3 pulpwood	331	5.3 saw timber 22.0 pulpwood
2020	Final Harvest	2,422	133.5 saw timber 15.2 pulpwood	2,071	112.3 saw timber 22.0 pulpwood
Present Net Value (@ 4%)		$623		$304	
Internal Rate of Return		12.4% 1/		10.1%	

1/ Based on 4% inflation rate assumed.

cal and biotic properties. Silvicultural operations, such as harvesting, site preparation and controlled burning can increase or decrease soil productivity by altering one or more of these three properties. Examples of silvicultural impacts on soil properties include nutrient removal, soil compaction and soil displacement.

3. The amount of nutrients available at the time of planting governs the rate of seedling growth and early stand development.

4. Soil compaction can adversely affect tree growth and many years are needed for soil compaction to break down and the soil to regain its original bulk density.

5. Growth differences observed during the first 5 to 10 years of stand development on upland sites will presist through a pulpwood rotation and likely to a sawlog rotation.

Several studies emphasize these principles and demonstrate economic feasibility of protecting soil (Dissmeyer 1985). The way a site is prepared for planting can make a .9 to 4.3 meter (3 to 14 foot) difference in site index for pine planted in uplands. Patterson (1984) evaluated a 1.5-meter (5-foot) site index difference obtained by protecting soil through light site preparation during a 36-year pulpwood rotation loblolly pine (*Pinus taeda*) in Alabama (Table 1). Light site preparation included practices such as chop and light burn or chop and herbicides. Both of these approaches reduce soil exposure, soil displacement, erosion, and sediment. In contrast, heavy site preparation, bulldozing and windrowing or shearing and windrowing, impaired soil productivity by nutrient removal caused by pushing litter, debris and topsoil into the windrows, and by soil compaction. The latter treatments also increased erosion and sediment yields over those for the light site preparation. Patterson's data reveals that investing $123 per hectare ($50 per acre) more in heavy site preparation reduced present net value of the timber by approximately $319 per hectare ($129 per acre) and reduce the rate of return from tree growth by 2.3 real percentage points. The 1.5-meter (5-foot) decrease in site quality resulted in less sawtimber and more pulpwood per acre. Conversely, maintaining site quality yielded larger trees and more valuable products.

A recent economic analysis of the watershed management program for the Forest Service's Southern Region showed that a 1.5-meter (5-foot) site index difference on a 70-year sawlog rotation, where the average site index was 70, resulted in a 28 cubic meter (1,000 cubic feet) higher yield of timber produced on the higher index site. That decreased yield cost the producer $227 per hectare ($92 per acre) in yield, besides costing him $74 to $123 per hectare ($30 to $50 per acre) in site preparation costs.

Logging operations with accompanying skid trails and roads are sources of sediment. Primary skid trails and roads are heavily compacted and exposed to erosion from repeated passes by skidding equipment. Hatchell (1970) reports that primary skid trails occupy an average of 12.4% of logged areas, secondary skid trails, 19.9%, and log decks, 1.5%.

Froehlich (1979) found a moderate amount of soil compaction in the root zones of ponderosa pine (*Pinus ponderosa*) reduced growth by 6% over a 16-year period. For heavily impacted root zones, he reports growth was reduced by 12%. Wert and Thomas (1981) found growth of 42-year-old Douglas fir (*Psuedosuga menziesii*) in primary skid trails was reduced by 74% compared to trees growing in undisturbed soil.

Table 2. Analysis of economic benefits of skid trail rehabilitation in the management of 3 southern timber types.

		Timber type		
	Units	Hardwood	Hardwood-Pine	Shortleaf Pine
Rotation	Years	70	60	60
Harvest volume per hectare	M^3	301	350	420
Value per cubic meter	\$2/	28.57	42.86	64.29
Total value of timber per hectare for uncompacted soil	\$2/	8,600	15,001	27,002
Timber volume per acre on skid trails (26% of uncompacted soil)	M^3	78	91	109
Timber volume lost per acre	M^3	223	259	311
Cost per hectare for skid trail rehabilitation 1/	\$2/	900	900	900
Timber volume recovered (75% of loss)	M^3	167	194	233
Value of timber volume recovered	\$2/	4,771	8,315	14,980
Internal rate of return based upon timber volume recovered	%3/	2.4	3.8	4.8
Net present value of timber volume recovered (@ 2%)	\$2/	1,193	2,538	4,568
B/C ratio of rehab. cost	Ratio	1.33:1	2.82:1	5.07:1

1/ Average cost per acre of skid trail for waterbarring, ripping of disking, seeding, fertilizing, and mulching where needed.

2/ 1986 dollars.

3/ Percentage points over inflation.

tchell (1970) loblolly pine (Pinus taeda) found eedling establishment and early growth in pri- ary skid trails were adversely affected by mpaction. He suggested discing or subsoiling break up the compaction and improve seedling tablishment and early growth. Hatchell (1981) lled and fertilized heavily compacted skid ails and landings and obtained growth of seed- ngs through age 4, that was close to the growth undisturbed soil.

e economics of primary skid trail and landings habilitation can be approximated using the data Wert and Thomas (1981). Benefits from skid ail rehabilitation for hardwood, hardwood/pine, d shortleaf pine on site index 70 (base 50 ars) land is estimated (Table 2).

aluated sawlog rotations of 60 to 70 years were ed. Table 2 shows the expected volume of mber per hectare and the value per cubic meter. rt's and Thomas' (1981) growth loss of 74% was ed to predict growth of timber on roads and id trails. The predictions showed 26% of the mber volume on skid trails as compared to that undisturbed soil. Growth losses on skid ails ranged between 223 and 311 cubic meters ,184 and 4,440 cubic feet) for the rotation.

tchell (1981) stated that long term growth uld not be projected from his 4-year study on e effects of compaction, but the data of ssmeyer (1985) and Amateis and Burkhart (1985), early (5-10 years) height differences between te preparation treatments on upland Coastal Plain and Piedmont sites show that differences persist to the end of pulpwood rotations. The growth curves presented by Dissmeyer (1985) and Amateis and Burkhart (1985) suggest that growth difference would probably also persist through 60-to 70-year sawlog rotations. Hatchell (1981) found that 4-year heights were the same between rehabilitated skid trails and uncompacted soil. Projecting to the end of a pulpwood rotation, the trees in the former skid trails should be about the same as trees growing on the uncompacted soil. For the purposes of this analysis, it was estimated that only 75% of the growth loss would be regained by skid trail rehabilitation.

The average cost to fully treat hectare of skid trail is \$900 (\$360 per acre). Full treatment includes waterbarring, ripping or discing, seeding, fertilizing, and mulching where needed. The present value of the timber productivity recovered ranges from \$1,193 to \$4,568 per hectare (\$477 to \$1,827 per acre). The benefit/cost ratio for hardwood is 1.33, for hardwood/pine - 2.82 and for shortleaf pine - 5.07.

The real rate of return over inflation ranges from 2.4 to 4.8%. The real rate of return of 2.4% for hardwood is comparable to low risk investments in government securities. The return of 3.8% for hardwood/pine is comparable to investments from low to medium risk income/growth mutual funds. The 4.8% return for shortleaf pine is comparable to returns from medium risk income/-growth mutual funds.

Table 3. Analysis of economic benefits of watershed treatments associated with roads.

	Treatment 1/		
	Seed Without Mulch	Seed With Mulch	Hydroseed & Mulch
Cost per kilometer - $	356	569	701
Cost per kilometer for soil and water technical services - $	62	62	62
Total cost of watershed treatment - $	418	631	763
Benefits			
Savings in construction costs - $/Km	311	311	311
Savings in annual maintenance costs - $/Km	186	186	186
Benefit/cost (10-year period)	4.4:1	2.9:1	2.4:1

1/ Treatments included fertilization and liming where needed.

It appears from this analysis that investment in skid trail rehabilitation will reduce sediment yields and benefit fisheries, and will also benefit landowners economically. The more valuable the timber product grown, the greater is the return on the investment. Investment in maintaining soil productivity can be as good as investments in some other long term options.

Roads can be a major source of erosion and sediment and rehabilitation appears to be economically justifiable. Reducing erosion and sediment from roads includes proper location, drainage, surfacing and revegetating cut and fill slopes. During a planning analysis, Jim Maxwell 2/ and engineers on the Chattahoochee-Oconee National Forest found the inclusion of soil and water resource management in the location and construction of forest roads results in an estimated $311 per kilometer ($500 per mile) savings in construction costs and an estimated annual savings of $186 per kilometer ($300 per mile) maintenance costs (Table 3). These savings in construction costs come from avoiding problem soils, wet areas, and unstable slopes. Maintenance savings are derived from the revegetated cut and fill slopes, which reduced erosion from these sources and prolonged the time needed for ditch lines to fill with sediment. Without revegetating cut and fill slopes, ditch lines need to be reconstructed one or more times a year. Vegetated fill slopes are more stable and less likely to erode or slump, thus fill slope maintenance costs are reduced. Also, proper spacing of road drainage decreases ditch and surface erosion.

The costs of revegetating cut and fill slopes ranges from $356 to $701 per kilometer ($573 to $1,128 per mile) depending on the amount of cut and fill area per mile and the type of treatment needed (Table 3). The costs of preparing soil and water prescriptions, soils data, and reviewing the project in the field is approximately $5 per kilometer ($100 per mile).

The benefit to cost analysis of rehabilitating cut and fill slopes was limited in my analysis (Table 3) to a 10-year period. For a seed without mulch treatment of cut and fill slopes, the benefit/cost ratio is 4.4. For seeding with mulch, the ratio is 2.9. The B/C ratio for hydroseeding is 2.4. Therefore, the analysis clearly shows that it is to the landowner's financial benefit to invest in soil and water consultation, and in revegetating cut and fill slopes on permanent access roads.

CONCLUSIONS

The control of sediment that adversely affects fisheries is best controlled at its source. Controlling erosion and sediment at its source i forestry, generally means in site preparation areas, logging areas, and roads. Erosion cont at these sources can mean significant economic benefit to the landowner through reduced road construction and maintenance costs, savings in site preparation costs, by increased timber pr duction and larger returns on investments. Wat quality and fisheries will also benefit. Prop soil and water resource management is good for the upstream landowner, to the downstream fish and water user, and to society in general. So and water conservation is not just a "nice thi to do", but makes good economic sense in fores

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2/ Personal communication and file data.

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Pine Plantations As Wildlife Habitat: A Perspective

A. Sydney Johnson

Abstract. -- Pine (Pinus spp.) forests in various stages of succession provide important seasonal habitat for many wildlife species, and open, frequently burned pine forests are crucial habitat for some species. But extensive unbroken tracts of pure pine are not good habitat for wildlife in general. Historical evidence indicates that the great abundance of wildlife in precolonial southern forests resulted from a mixture of forest types with abundant old growth and substantial areas of openings and early successional forests interspersed. Extensive pine barrens supported relatively little wildlife. On pine sites the diversity of age classes provided by modern even-age forest management can provide good habitat for more vertebrate species than some of the original pine forests, but much depends upon how forests are managed. Hardwoods are essential for most wildlife species. The conversion and attempted conversion of hardwood sites to pine often has been counter to wildlife interests, but the current trend toward less intensive timber management on marginal sites probably is beneficial. The vagaries of economics will determine the place of wildlife in southern forests. In recent years the economic position of game animals relative to timber has improved and may provide additional incentive for incorporating wildlife enhancement measures into forest management plans.

INTRODUCTION

There has been much research on wildlife responses to intensive forest management and it has been summarized and interpreted, frequently, in review articles (Speake 1970, Perkins 1974, Johnson et al. 1974, Harris and Smith 1978, Harris and Skoog 1980, Dickson 1981). Yet pine plantations continue to be discussed with strong opinions often based on inadequate information. Some writers (e.g. Wheeler 1970) contend that the diversity of age classes provided by intensive forest management results in more game animals than when the Indians were here; others (e.g. Margolin 1970) maintain that pine plantations are "biological deserts.".

Evidence discussed in this paper indicates that wildlife was very abundant over most of the Southeast "when the Indians were here"--not because the region was unbroken virgin forest, but because there was great diversity, and disturbance was frequent and extensive. Even then, however, there were areas of pure pine forest that were regarded as "barrens" or "desert." Then, as now, open pine stands that were frequently burned were important habitat for some wildlife species, but fully stocked pine stands after crown closure were not good wild habitat. Thus, the "biological desert" parad often fits individual pine stands after crown closure. However, before crown closure, pine stands provide excellent year-round or season habitat for a variety of wildlife species. T specific wildlife values of young pine stands change rapidly. Therefore, if stands of diffe ent ages are interspersed and key areas of hardwood are maintained, pine forests can be wildlife habitat, and timber and wildlife mana ment can be effectively and economically coor nated. The discussion that follows develops these points more fully. I thank P. E. Hale, L. Landers, and J. M. Wentworth for reviewing manuscript and providing helpful suggestions.

THE ORIGINAL FORESTS

Most foresters and wildlife biologists assume that managed lands are more productive than unmanaged or wild lands. And, knowing t most wildlife species are favored by early st of forest succession, many readily accept the conclusion that today's managed forests have wildlife than those first encountered here by Europeans (e.g. McGinnes and Reeves 1958, Elde

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1965, Newsom 1969, Wheeler 1970). This conclusion is supported by accounts of the scarcity of game encountered by the Lewis and Clark Expedition (Thwaites 1959) and certain other explorers in the northwestern part of the continent. However, for most of the eastern part of the continent, even a superficial review of historical literature will raise doubt about this conclusion. Early travelers obviously were awed by the abundance and variety of wildlife and, although some early writers are known to have exaggerated, there are so many similar reports that they cannot be dismissed. Many of these statements have been extracted and compiled for wild turkeys (Meleagris gallopavo) (Wright 1915) and white-tailed deer (Odocoileus virginianus) (McCabe and McCabe 1984).

In addition to narratives, there are market and export records for skins and other commodities. Except for fish, the white-tailed deer was the most important animal food of Indians in the eastern states, and deer hides were important commercial items. Therefore, a good record exists from which to judge its numbers. McCabe and McCabe (1984:29) estimated that precolonial Indians in what is now Canada and the United States consumed 4.6 to 6.4 million deer per year--about twice the number harvested in the two countries in 1982 (3.0 million--Stransky 1984:739). Yet, the age structure of the harvest as determined from deer jawbones from Indian middens, indicates that a low percentage of the population was being harvested (McGinnes and Reeves 1958:9 and Elder 1965).

In the late 1600's to the mid-1700's deer hides became the most important export item from the Southeast, and the rate of harvest greatly increased. The number of hides exported from Charleston, South Carolina, averaged 151,000 per year from 1739 to 1765 (McCabe and McCabe 1984:26). These exports are in addition to deer hides used domestically by Indians and white colonists and probably do not even include all deer exported from South Carolina. Nevertheless, the average annual export was almost three times the number of deer harvested in the state in 1982 (54,321--Stransky 1984:739). Similar numbers of deer hides were shipped from ports in Georgia and the Pensacola Florida-Mobile Alabama area, and smaller numbers were shipped from other ports in these states (Young 1956:23; Wing 1965; McCabe and McCabe 1984:26). These harvest rates were sustained for decades before deer populations diminished under the intense hunting pressure and the increasing impact of white settlers. Narrative accounts and other information indicate that other game species also were present in much greater numbers than today.

Of course there was much more habitat then, and this partly accounts for the large numbers and great diversity of wildlife. But it is clear that densities of deer, wild turkeys, and other species were very high in some areas. It is instructive for the manager to examine precolonial forest conditions that supported such an abundance of wildlife.

The general composition and nature of the original forests (i.e., those encountered by the earliest European colonists) can be reconstructed from early accounts and statistics (e.g. Nelson 1957, Rostlund 1957), analysis of corner and witness trees in land survey records (Jones and Patton 1966; Rankin and Davis 1971; Plummer 1975; and Delcourt and Delcourt 1974, 1977), and relatively detailed descriptions of remnant forests in the late 1800's and early 1900's (e.g. Ashe 1894; Mohr 1901, Dunston 1910, Harper 1914, 1920, 1943). It is clear from these sources of information that, with some definite exceptions, the original forests of the Southeast were very diverse, with distinct forest types that were closely related to soil types.

The Piedmont forests, like those of the Blue Ridge, Ridge and Valley, and Plateau regions, were mixed forests with a preponderance (53%) of oak (Quercus spp.). The red soils, which occupied 35-40% of the Piedmont, supported very little pine. Gray, sandy soils supported mixed pine-hardwood forests, and only about 15% of the Piedmont was predominantly pine (Nelson 1957, Plummer 1975).

Coastal Plain forest conditions were determined mainly by topography and soils interacting with fire. Pine forests were extensive. Sandy, infertile uplands supported forests of almost pure longleaf pine (Pinus palustris). Hardwoods were excluded by soil characteristics and frequent fire. In many areas pines were widely spaced and early accounts refer to extensive pine savannas (Plummer 1975), but some of the pine forests were described as very dense (Lane 1973:148, 156). Where soils contained more clay, hardwoods, especially oaks, were interspersed among the pines and often dominated. Moist, fertile sites protected from fire often supported magnolia (Magnolia grandiflora), beech (Fagus grandifolia), and other mesic hardwoods, especially in the Gulf Coastal Plain (Delcourt and Delcourt 1974, 1977). About one-third of the Black Belt was patches of prairie or savanna (≤10 trees/acre) on alkaline soils, and the forests, which occurred on the acidic soils, were only 5-10% pine (Jones and Patton 1966, Rankin and Davis 1971). In Georgia about one-third of the Lower Coastal Plain was hardwood, gum-cypress (Nyssa-Taxodium), or cane (Arundinaria gigantea) swamp (Bartram 1792:28, Lane 1973:52). Along the slopes between the swamps and the pine uplands, forests graded from hardwood to pine-hardwood to pine. A band of live oak (Q. virginiana) forest extended inland a short distance from the coast (Plummer 1975). In the Carolinas, bays and pocosins supporting hardwood-cypress swamp, shrub bog, or wet prairie added other elements of diversity.

The old growth forests must have produced mast in quantities difficult to imagine today, and the abundance of acorns and chestnuts (Castanea dentata), clearly were important in supporting dense populations of turkeys, deer, passenger pigeons (Ectopistes migratorius), and other species. But, over the Southeast as a whole, unbroken expanses of even-aged old growth forest were much less common than generally imagined.

Indians were the major factor affecting the forests, although lightning, wind, and ice storms--often followed by fire--were also significant forces of disturbance. Indians practiced agriculture extensively, clearing land by girdling trees and burning (Swanton 1946:304-310). Some areas near large towns were farmed continuously, but many fields were cropped for only a few seasons then abandoned for new clearings. Some of the abandoned fields became grasslands maintained by repeated burning. Rostlund (1957) made an extensive review of accounts of precolonial vegetation in the Southeast and concluded that prairies and savannas made up a considerable part of the region. He quoted references to grasslands and cultivated fields in nearly every state and physiographic province from Virginia to the Mississippi River. Some referred to grasslands or savannas extending for miles. The Indian population over much of the Southeast was drastically reduced between 1560 and 1700 (Swanton 1946:11-21), and some of the dense pine forests described later may have been established on abandoned Indian fields.

The diverse pattern of vegetation that has been reconstructed is consistent with the the accounts of abundant wildlife. The intermingling of mature forests, deadened timber, savannas, grasslands, and agricultural fields provided near optimum conditions for wildlife. The Indians, probably unintentionally, practiced far better wildlife habitat management than managers can affort to today.

However, wildlife was not uniformly abundant. Although early writers seldom provided enough detail for comparison of wildlife abundance in specific habitats, descriptions of extensive "pine barrens" in parts of the Coastal Plain contrast sharply with the often poetic descriptions of the more diverse forests on better soils.

For example, John Davis, travelling through an "endless track of pines," between Charleston and Georgetown, South Carolina about 1800, wrote of the "awful solitude of the woods ... heard no sound but that of a woodpecker" (Cheney 1910:138-139).

Several English travellers wrote of a stage route along the fall line across Georgia before 1830. John Melish in 1806 described the route about 25 miles south of Augusta, Georgia, as "completely barren, and covered with pine trees ..." He was one of several travellers to use the term "desert" (Lane 1973:21, 26). Adam Hodgson, at Macon in 1820, wrote " ... from the fort the eye looks down on an unbroken mass of pine woods, which lose themselves on every side in the horizon about twenty miles distant" (Lane 1973: 57). And Basil Hall, writing about the area southeast of Macon in 1828, said "When one gets into an American pine barren, it looks as if it would never end" (Lane 1973:78).

James Silk Buckingham travelled this route from Augusta to Columbus, in 1828. Between Warrenton and Sparta, "our road lay almost wholly through dense pine-forests, and the constant succession of these trees, with scarcely any other variety, made the way gloomy and monotonous." Just west of Macon: " ... a dense forest of pine-trees, the aspect of which was gloomy and monotonous in the extreme." And, still farther west, "in the woods, the turtle-dove was the only bird we saw in any numbers; a solitary mockingbird was occasionally seen; but though it was now (early spring), we were never once cheered, in all our journey, by the sounds of the feathered choir, that make the woods of 'merry England' redolent of song" (Lane 1973: 148, 156, 157).

These descriptions of some of the pine forests encountered by early settlers are strikingly similar to those used by today's critics of extensive pine plantations. Plummer's (1975) analysis of original land survey records showed that the true pine flatwoods (southeastern Georgia) had very few tree species. The forest he described would have had little midstory or woody understory and little mast production. These conditions were favorable for a relatively few wildlife species. Outside the coastal flatwoods and sandhills, especially on the Gulf slope, pine forests were more diverse (Plummer 1975) and probably supported much more wildlife. Although deer, bear (Ursus americanus), and wild turkey used the pine forests and were abundant in at least parts of the pine region, they seem to have been associated with the hardwood swamps that dissected much of the area. For example, most early references to wild turkeys that mentioned food or habitat conditions referred to oaks, acorns, or clearings (Wright 1915).

However, it is important to recognize that frequently burned, open, mature pine forests were then, and are today, crucial habitat for some species. These include endangered and other nongame species of special interest--such as the red-cockaded woodpecker (Picoides borealis, Hooper et al. 1980), gopher-tortoise and eastern indigo snake (Gopherus polyphemus and Drymarchon corais couperi, Landers and Speake 1980)--and important game species, such as the bobwhite quail (Colinus virginianus, Landers 1981).

TODAY'S NATURAL FORESTS

The original forests were cleared rapidly as agricultural settlement swept through the South in the early 1800's; the last remnants were cut from 1880 to 1920. In most places original forest conditions cannot be restored-- soils have been modified, the equilibrium of species has been upset, and important species have been lost. Today's "natural" forests--those that regenerate naturally on cutover lands and lands abandoned from agriculture, 1865-1950--differ substantiall om those they replaced. Because they regene- ted following severe and extensive disturbance griculture or clearcutting), today's natural ands are more nearly even-aged and, of course, ch younger than the original forests. Those on andoned agricultural fields usually have little ody understory.

In the Piedmont, soil-disturbance and wered site quality resulting from erosion have lowed loblolly pine (*Pinus taeda*) to become minant on sites formerly occupied by hardwood mixed stands, and on most pine sites loblolly ne has displaced shortleaf pine (*P. echinata*). nversely, in much of the Coastal Plain agricul- ral fertilization and fire exclusion have lowed hardwoods and slash pine (*P. elliottii*) invade sites originally occupied by longleaf ne. Unfortunately, much of the hardwood vading the pine type is of relatively little lue to wildlife because it consists of species ch as sweetgum (*Liquidambar styraciflua*). And thout selective thinning or burning or both, en desirable species usually remain suppressed the understory and contribute little mast, owse, or cavities. But, where wildlife is a jor objective in management, as on some public nds and game plantations, naturally regenerated ne forests managed on a long rotation with equent prescribed burning are near optimum bitat for many species.

Naturally regenerated pine stands are still mmon on private nonindustrial lands and on blic lands, but on most forest industry lands ey have been replaced by plantations.

NE PLANTATIONS

Plantations differ from today's natural ands in several respects. Whereas many natural ands regenerated following high-grade logging, st plantations follow agriculture or intensive chanical site preparation and have less residu- hardwood rootstock. In some areas drainage d other site preparation allows conversion of press or hardwood sites to pine sites. Pine antations are more uniform in species composi- on, spacing, and age than are natural stands, d they are usually managed on a short rotation. nerally, these differences would have to be garded as unfavorable to wildlife. But, it uld be too simplistic to conclude that natural ands are always better wildlife habitat.

Because plantation establishment replaces e type of habitat with a very different one, it difficult to compare plantations with natural ands without carefully replicated experimental udies over a long period of time. Thus, most blished studies have compared plantations with tural stands of different and highly variable ecies composition and generally of different e (Harris et al. 1974, Noble and Hamilton 1975, ckson and Segelquist 1979, Hurst and Warren 80, Repenning and Labisky 1985). As would be pected, these studies usually show substantial- different wildlife values for the different habitats. However, on wet flatwoods sites naturally occupied by slash pine and unfavorable for growth of most hardwoods, natural and planted stands are more similar in species composition than on other sites. On such an area in southeastern Georgia, Johnson and Landers (1982 and unpublished) compared midsummer bird populations, small mammals, and certain vegetational characters in 40 slash pine plantations 11 to 28 years old and an equal number of naturally regenerated slash pine stands of the same ages. The naturally regenerated stands were less densely stocked with pines than the plantations, which had 40-60% more trees. Canopy closure occurred later and woody understory cover was about 20% more dense in the naturally regenerated stands. Reflecting the earlier canopy closure of the plantations, density and number of species of summer resident birds were lower in plantations than natural stands at ages 11-15. But, after age 15, despite continued differences in understory and overstory density of the two types of stands, differences in bird populations were not detectable. Trapping success for small mammals was mostly related to local site variation (soil drainage), and differences between natural and planted stands were not evident.

Because plantations are, by definition, managed systems, their wildlife value cannot be assessed without consideration of the management practices applied to them. If optimization of timber management as the sole objective could be realized, most wildlife would be affected adversely and there would be no place for some species. Many of the goals of intensive timber management seem contrary to the goals of wildlife habitat management. For example, wildlife habitat managers usually strive for a diverse overstory, sparsely stocked to allow understory development, and a long rotation with trees old enough to produce good mast crops and form cavities. Commercial timber growers want full site occupancy by the commercially desired species, a short time between investment and return on the investment, high growth and yield rates, and economic efficiency in management. These timber management goals are pursued by full stocking, elimination of competition, short rotations, use of genetically improved strains, fertilization, large management units, mechanization, and a high-density road system. If these goals were fully achieved, the intensively managed forest would indeed be very poor wildlife habitat. This view of pine plantations caused many wildlife biologists during the 1950's and 1960's to dismiss industrial forest lands as hopeless.

In the 1970's several things became evident that caused many biologists to change their views. First, because of various economic and public relations incentives and sometimes personal interests of managers or executives, wildlife often *is* given consideration in the management of industrial forests. Second, even where the goals of timber management are pursued intensively and single-mindedly, they are rarely achieved because of economic, topographic, and environmental limitations. And finally, biologists recognized that the 30,000,000 or so acres of industrial forest land in the Southeast offers a great opportunity to increase wildlife production, hunting, and other wildlife-oriented recreation.

Before crown closure, pine plantations of different ages provide excellent year round habitat for early successional species--such as quail, rabbits (*Sylvilagus floridanus*), small mammals, and their predators--and seasonal habitat for many other species, including important game animals such as deer and turkey. Wildlife use of young pine plantations has been intensively studied and is the subject of many publications (e.g. Brunswig and Johnson 1972, Johnson et al. 1974, Atkeson and Johnson 1979, Landers and Buckner 1979, Buckner and Landers 1980). It is clear from these studies that, by providing a mosaic of different age classes, managed pine forests may support a variety of wildlife species and greater abundance of some species than the original unbroken pine barrens. But a hardwood component must be maintained on hardwood sites for animals, such as gray squirrels (*Sciurus carolinensis*) and many species of wood warblers (Parulidae), that depend on hardwoods and to provide mast, which is important to wild turkeys, deer, bear, raccoons (*Procyon lotor*), and other wildlife.

If wildlife is given consideration in management planning, many wildlife enhancement measures can be incorporated at little cost, especially considering other environmental and public relations benefits and the market potential for wildlife-related recreation. Because of economic factors, the trend in the forest industry at this time is toward less intensive management on marginal sites. Furthermore, the economic position of game species relative to timber production has improved significantly in the last few years. These trends, if they continue, should result in increased opportunities for management of at least some important game species.

Guidelines for coordination of timber and wildlife management in southern forests are already available (Johnson et. al 1974, Harris et. al 1979, Buckner and Landers 1980, Harris and Marion 1982, and Landers 1985), and other papers in this session deal with the economics and application of specific forestry practices. But a few generalizations can be offered.

The most challenging aspect of coordinating short-rotation timber and wildlife management, obviously, is maintenance of areas of mature hardwoods and old-growth pine. Site conversion (e.g. drainage) and streamside management zones are perhaps the most important issues in timber-wildlife coordination. Maintaining units of hardwood and old growth, linked by travel corridors and streamside management zones, is crucial to the wildlife objective. In general it is best to maintain hardwoods in stands on hardwood sites rather than having them dispersed within pine stands.

Wildlife may be most effectively incorporated into timber management by planning the size, shape, and arrangement of stands and scheduling harvest and intermediate treatments for desired wildlife benefits. Ideally, the pattern should be such that all the needs of a species are fulfilled in any area of home range size on the tract. This ideal is rarely achieved; and if a variety of wildlife species are considered, it may be impossible. The goal is best approached by careful juxtaposition of small stands so that diversity and patchiness are maintained. But it is important that critical habitats are connecte by corridors and streamside management zones. Otherwise habitats may become fragmented into scattered islands too small to support breeding populations and too isolated for use by other populations. This aspect of management is discussed by Harris and Smith (1978), Buckner an Landers (1980), Harris and Marion (1982), and Harris (1983).

Intensity of management within stands also is an important consideration. Decisions regarding site preparation, planting, and intermediate treatments such as fertilization, chemical weed control, prescribed burning, and thinnings can greatly affect wildlife, and several papers on this program elaborate on certain of these. Others are discussed by Johnson et al. (1974), Buckner and Landers (1980), and Landers (1985). If the wildlife objective is considered in these activities, benefits may be obtained at little c no cost to the timber objective.

Finally, the responses of vegetation and wildlife to silvicultural practices may differ drastically at different places and different times depending upon site characteristics, previous use of the land, and weather conditions. Site is an especially important consideration. Foresters generally are acutely aware of the importance of site in timber management, but they often fail to recognize that site characteristics may dictate different strategies in wildlife habitat management. Some sites seemingly resist management; others respond readily (Johnson et al. 1974, Landers 1985). Johnson et al. (1986) pointed out that in deer management, blanket prescriptions across a variety of sites may benefit deer populations in some areas and have adverse effects in others.

In summary, pine plantations alone can not fully meet the needs of all wildlife species, b they can provide good habitat for many species. Much depends upon how they are managed. The wildlife habitat managers' goal, which must be pursued with an acute awareness of economic reality, is to arrange stands so as to maintain pattern of high diversity in structure, age, an timber types and to maintain mast-producing hardwoods on hardwood sites to the extent feasible.

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Prescribed Burning for Managing Wildlife in Southeastern Pine Forests

J. Larry Landers

Abstract.--Reports involving today's wildfires or prescribed burns often fail to recognize fire's primal influence on wild animals. There is much ecological evidence that recurring fires have been a long-standing, evolutionary agent of habitat change to which native species are adapted in the Southeast. Wildlife mortality from flames or smoke is generally insignificant in southern forests. Many upland, resident species thrive in herb-shrub stages that occur in post-fire succession beneath pine (*Pinus* spp.) canopies, and these species diminish when hardwood overstories begin to overshade lower plant strata. Wildlife species characteristic of complete hardwood overstories should be maintained on true hardwood sites where fire rarely penetrated naturally. Brushy patches, inclusions of deciduous subcanopies, and groups of large living and dead hardwoods add diversity to open pine forests with grassy-forb groundstories. Interspersion could be enhanced in the short term by spot burning under moist conditions together with protection of selected parcels, but on many sites a hotter fire is needed periodically to refurbish the open pine community. Research is needed to determine the proportion at which habitat components should be placed together to support different wildlife assemblages. Long-term studies of the effects of fire or its exclusion on forest communities would also help land managers choose appropriate burning schedules to reach wildlife objectives.

INTRODUCTION

Ecologists have long recognized that ghtning-set fires must have been a recurring rce in original forests of the Southeast for at ast 8000 years (Harper 1911, Heyward 1939). us, there are many examples that show resident ldlife species to be adapted to fire, if not pendent upon it. During most of that period erican Indians apparently set fires to drive me as well as to meet other objectives. Natural re regimes were further altered by settlers--rough range burning with livestock grazing, tensive farming, and lumbering--and by bsequent eras of fire protection and modern land es.

By the time research-based wildlife nagement emerged in this country (early 1920s) ere were no virgin tracts left in the Southeast mote or large enough to experience lightning-set re at its natural frequency. The historical lationships between fire, natural plant mmunities, and wildlife niches are essentially unknown. Thus, wildlife management is primarily involved with on-the-ground judgment guided by observations, and the use of prescribed burning to influence wild animal populations is still very much an art.

This report summarizes the effects of fire on selected wildlife species and fire's relation to habitat management in southeastern pine forests. I appreciate the helpful comments on this manuscript by James G. Dickson, Lowell K. Halls, A. Sydney Johnson, Roy Komarek, Brad S. Mueller, and Dan W. Speake.

DIRECT EFFECTS OF FIRE

Some behavioral reactions of vertebrate animals to burning have been summarized in a report pertaining mostly to wildfire (Lyon *et al.* 1978). It has been commonly observed that less mobile species, such as small rodents, are most likely to panic while larger animals usually move calmly during a fire. White-tailed deer

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(*Odocoileus virginianus*) are known to congregate on burned-over range and lick the ash residue, apparently to obtain minerals. Upland game birds, raptors and many smaller birds often are attracted to fire or to the smoking landscape as foraging sites.

Deaths of wild animals are seldom attributed to fire in the Southeast. Apparently, birds rarely succumb to fires (Bendell 1974). Means and Campbell (1981) noted deaths of several glass lizards (*Ophisaurus* spp.) and several diamondback rattlesnakes (*Crotalus adamanteus*) in mid-ecdysis (preshedding stage) at the time of prescribed burning, but they went on to say that very few herps are thus killed in southeastern forests. Similarly, review papers edited by Wood (1981) listed no fire-induced mortality of tree squirrels, furbearers, or black bears (*Ursus americanus*). Hill (1981) reviewed mortalities of rabbits in northern and western habitats caused by wildfires or intense summer burns, but he did not list specific incidents involving southeastern forests. However, after a fast-moving experimental fire through a South Florida prairie, Taylor (1981) recovered carcasses of five marsh rabbits (*Sylvilagus palustris*) on a 20-ha. plot; some degree of susceptibility of this species was noted previously by Komarek (1969). The more widespread cottontail (*S. floridanus*) seems to easily escape flames, as do most of the smaller mammals which inhabit upland sites. The ability of small mammals to go underground or to emigrate apparently accounts for the scant evidence of mortality from heat or suffocating smoke (Taylor 1981).

In a review by Stransky and Harlow (1981) no records of deer death by fire were noted. But recently, Osborne *et al*. (1986) documented numerous deer deaths in a North Carolina pocosin after a wildfire had moved through during a dry period; carcasses were typically found in smoldering hollows within the peat soils. Deer mortality to this extent has not been reported in other southeastern habitat types and most likely did not occur under natural fire regimes.

Indications are that fast-moving burns in habitats of the less mobile species would likely be involved when death results. When mortality does occur, it is usually negligible at the population level (Lyon *et al*. 1978). A proper evaluation should include the effective loss to the population in relation to losses that would have occurred through other causes had the burn not taken place (cf. Cringham 1958). Most undesirable direct effects can be overcome by choosing proper times, places, and methods for prescribed burning.

INDIRECT INFLUENCE OF FIRE

Fire makes its most important impact on wildlife through habitat alteration. There are many variables involving vegetation types, soil properties, topography, animal niches, and characteristics of individual fires that would require species-by-species accounts for thorough discussion. Such detailed analyses are beyond th scope of this report. Therefore, general conclusions of several publications are presented here to form overviews of wildlife groups.

Reptiles and Amphibians

Habitats of herps span the entire moisture gradient from xeric to aquatic. Certain very dry forest types in the southeastern Coastal Plain ar inhabited by species which travel in loose sand (sand-swimmers) or live just above sandy substrates. This group depends upon sites open a ground level, particularly those associated with patches of turkey oak (*Quercus laevis*) within longleaf pine (*Pinus palustris*)-wiregrass (*Aristida stricta*) communities or young sand pine (*P. clausa*) stands (Campbell and Christman 1982). Because sand ridges must have periodic fire to keep dense hardwoods from dominating the landscap (Bozeman 1971), reptiles keyed to these open habitats are considered likewise dependent. Another sand ridge reptile, the gopher tortoise (*Gopherus polyphemus*), burrows and nests in sunli sites and thrives on herbaceous plants that are dependent on frequent fire; several other rare or threatened herps and many common species utilizin tortoise burrows are indirectly benefited by fire (Landers and Speake 1980).

Mesic forests support a less site-specific herpetofauna. For example, Means and Campbell (1981) captured 38 species in a study conducted i northern Florida red hills. Three amphibian and reptile species were predominantly in annually burned pine forests, and 3 amphibians were predominantly in hardwood hammock; the rest were not clearly site specific. These authors also summarized results from a summer burn in longleaf pine flatwoods and from a winter burn in slash pine (*Pinus elliottii*) flatwoods. The overall trap take reached a new high one month post burning on the longleaf site, and the herp specie dependent on surface cover did not show a population decline after the burn; 26 species wer active throughout the burned area. In the slash pine study there was no noticeable decline in tra take of any species following winter burning.

Very little information is available regarding the more aquatic herps. Those which thrive in or adjacent to sizable water bodies are probably affected very little by fire. The American alligator (*Alligator mississippiensis*) and associated marsh animals benefit from occasional burning of shoreline vegetation (Lyon *et al*. 1978). Species which inhabit small bogs, such as the pine barrens treefrog (*Hyla andersoni*), depend on fires to prevent woody plants from dominating their sites (Means and Moler 1979).

Much more research is needed to clarify relationships between fire and herp species. However, existing data indicate that prescribed burning benefits most species native to southern pine forests (Means and Campbell 1981).

Birds

Fire is one of the most important factors determining the abundance of forest birds. Avian food resources are strongly affected by burning. Total seed production peaks the first growing season after fire and quickly decreases thereafter (Buckner and Landers 1979). Fleshy fruits are severely reduced the first year after a fire except in cases where the more fire-tolerant species such as dogwood (Cornus florida) or beautyberry (Callicarpa americana) are present. These plants may actually produce more fruits at this time. In open pine flatwoods, fruits of most shrubs peak three to five years thereafter (Johnson and Landers 1978). Understory burning may induce longer-term reduction of most soft mast species on certain upland pine-hardwood sites (Lay 1956).

The litter-dwelling forms of invertebrates eaten by birds are reduced by ground fires in the short term; herbivorous insects quickly increase with the regrowth of succulent plants; and certain species of flies and beetles are drawn to the smoke and heat, or later, to damaged trees (Dickson 1981). These changes may affect reproductive success because arthropods supply critical nutrients for breeding birds.

The physical makeup of bird habitat is also of great importance. Structurally complex areas generally support a greater diversity of birds than uniform habitats, so fire can strongly influence the composition of avian assemblages through its effects on vegetation.

Nongame Forest Birds.--Only general iscussions are available on most resident birds n the Southeast. Conner (1981) drew several ertinent conclusions regarding cavity users. He ointed out that woodpeckers and secondary cavity sers will decline where fire eliminates snags. imilarly, the ignition of pine gum associated ith red-cockaded woodpecker (Picoides borealis) avities can reduce nest sites which are a very imited resource in most of today's forests. ertain foods of woodpeckers can dwindle when fire educes litter-dwelling insects, deciduous foliage upporting caterpillars, and the availability of corns and other important fruits. Conner (1981) lso listed some potential benefits: new snags re often created by burns, especially in old-rowth forests; low, open understories haracteristic of burned areas are essential to ed-cockaded woodpeckers; production of certain ruits eaten after the breeding season can ncrease with prescribed burning; many bird pecies are drawn to residual foods in burned-over reas; and fire provides open feeding grounds here birds capture ants, grasshoppers and piders. The complexity of the potential negative s. positive effects on cavity-users points out he need for research on maintaining needed iversity through careful burning techniques.

In a review of songbirds, Dickson (1981) ndicated that burning favors the species closely ied to pine stands or early successional vegetation; it selects against those dependent on deciduous canopy foliage, midstory trees, or litter accumulation; and "edge species" may depend on a habitat interface such as occurs at the edge of burns or around hardwood islands within open pine forests.

The fertility of pine sites may have a pronounced influence on bird habitat development. Studies in slash pine stands show that winter burning has little overall effect, apparently because resident birds resume site faithfulness immediately afterwards (Emlen 1970) and because subsequent midstory recovery is too slow to markedly effect bird diversity, at least during 5-year burn intervals (Johnson and Landers 1982). Since warm-season fires formerly entered these poor soil habitats every few years (Wharton 1978) and these fires inhibit hardwoods and shrubs much more than winter burns, it is probable that deciduous canopy birds were originally restricted to wet hardwood drains rather than being common residents of pine stands. This deduction might also apply to the infertile, dry soils of the Coastal Plain where summer fires thoroughly inhibited hardwoods. On the other hand, the mesic clay regions (parts of the Coastal Plain and Piedmont) probably experienced natural fires less frequently and responded quickly after a burn. Bush birds and midstory leaf-gleaners would most likely increase with the rapid post-fire succession. They were probably ephemeral in richer pine forests as well as regular residents of hardwood flats.

Diversity and abundance of birds would be enhanced in areas with a mixture of grasslands and multilayered hardwoods interspersed in open pine forests. These diverse conditions can be achieved by applying fires that result in patchy vegetation (spot burning under moist conditions, etc.) and by sparing selected hardwood areas from fire.

Upland Game Birds.--Habitat requirements of upland game birds have been thoroughly studied but there are still many gaps in knowledge of fire effects. Mourning doves (Zenaida macroura) commonly forage on fresh burns (Stoddard 1963a). Such bare areas are particularly important where doves do not have access to the kinds of seeds produced by mechanical soil disturbance. It might be deduced that, before man's influence, the mourning dove had to be a follower of fresh burns because it generally does not scratch in litter for seeds, nor does it alight in dense vegetation when feeding. The tendency for doves to nest in small trees or occasionally in lower plant strata also indicates that periodic fire may have been beneficial in providing early successional stages.

Gallinaceous game birds are affected by fire in several ways. Parasites that infect this bird group are reduced by burning (Stoddard 1931, Metz and Farrier 1971, Ahlgren 1974, Bendell 1974, Jacobson and Hurst 1979). In pine forests, bobwhite (Colinus virginianus) and wild turkey (Meleagris gallopavo) brood habitat consists primarily of recently burned herbaceous vegetation (Stoddard 1931, Exum 1985).

Cool weather foods of quail and turkey that increase the first year after burning include legumes and certain other large-seeded herbs. Many shrubs and midstory trees will increase fruit production if burned occasionally. Because acorn production declines in many areas with frequent burning, protection of oak patches has been recommended in habitat management of both quail (McRae *et al*. 1979) and turkey (Hurst 1981).

Annual winter burning over most of a management area is essential to maintaining huntable populations of quail in pine forests (Stoddard 1931, Speake 1966). Although responses of turkey populations are less clear, studies of important requirements (plant food diversity, insect production, brood-rearing sites, etc.) indicate that occasional burning is necessary to keep pine-dominated forests from becoming choked with brush (Hurst 1981). Recommendations for habitat maintenance range from burning turkey brood areas at least every other year (Exum 1985) to a general interval of once every three years (Stoddard 1963b). Burning before the nesting season is often recommended, with small, scattered areas burned each year throughout winter for regular production of greenery (Stoddard 1963b) and others every 2-4 years to insure some fruit production (Speake *et al*. 1975).

Ruffed grouse (*Bonasa umbellus*) select herbaceous habitats for brood rearing (Harris 1981). One of the major winter forages (*Kalmia latifolia*) of grouse in the Southeast has been shown to increase in crude protein and phosphorus with burning (Thackston *et al*. 1982). This game bird is considered a fire climax species, or at least one that benefits from recurring fires (Sharp 1970).

Birds of Prey.--Predatory birds are indirectly affected through fire's influence on nesting sites and food supplies. Red-tailed hawks (*Buteo jamaicensis*) have been recorded feeding on grasshoppers fleeing from fires. Kestrels (*Falco sparverius*) and many other hawks and owls also are attracted to burns in search of prey (Stoddard 1963a, Komarek 1969).

An important factor in the ecology of most predatory birds is the population level of prey species. Most hawks and owls depend on the cotton rat (*Sigmodon hispidus*) and cottontail rabbit and other major prey species (herps, large insects, etc.) that are affected by any disturbance that changes the balance between understory cover and forage. Since regular burning keeps habitat in a suitable condition for the more common mammals but temporarily exposes them when cover is ignited, and since thickets retard the efficiency of predators, it is probable that fire benefits avian predators through availability of food (see *Mammal* section). The maintenance of prey populations for golden eagles (*Aquila chrysaetos*) is an objective of burning mountain balds in the Southeast.

Cooper's and sharp-shinned hawks (*Accipiter cooperii* and *A. striatus*) seem to key in on quail and the larger or more colorful passerines. These "blue darter" hawks are primary predators of such birds that are abundant in fire-maintained game lands in the Deep South.

Because hawks nest mainly in living hardwood and the more widespread owl species nest in tree cavities, fire has the potential to adversely affect reproduction if it is intense enough to destroy nest trees. Light winter burning probabl does no substantial harm.

The burrowing owl (*Athene cunicularia*) inhabits sand hills in southern Florida. Periodi fire is important in keeping the substrate open for burrowing, as well as maintaining early successional stages for the herp-mammal food base on which this owl depends.

Mammals

A variety of mammals inhabit each stage of understory and subcanopy development in southern pine forests. No single species satisfies all of its seasonal needs in any one uniform stage. Rather, their dietary and structural requirements are partially in opposition because of competitio for sunlight within a stratum and progressive dominance of taller strata over shorter ones. Therefore, some degree of habitat patchiness is essential to all mammal species; the acceptable scale of this patchiness is related to the home range size of the species under consideration.

Small mammals.--Of the 44 species of small mammals in the southeastern states, only 16 had been mentioned in research reports when Taylor (1981) reviewed the literature regarding fire effects. He concluded that the fulvous harvest mouse (*Reithrodontomys fulvescens*) and cotton mouse (*Peromyscus gossypinus*) showed a consisten population increase following fire; the cotton rat, eastern harvest mouse (*R. humulis*), and round-tailed muskrat (*Neofiber alleni*) showed population decreases; the old-field mouse (*P. polionotus*) and Florida mouse (*P. floridanus*) showed no measurable change; and nine other species were listed under "response unknown."

The problem with deciphering small mammal responses is related to the very short duration most studies. The previous evaluation was heavi influenced by data from ten studies conducted fr 4 to 28 months; one investigation (Layne 1974) conducted over a three-year period and another (Baker unpubl.) had run for seven years at the time of Taylor's (1981) review. The complete impact of forest burning is difficult to assess because (1) erratic annual population changes ca occur independent of habitat conditions, (2) several years are required for significant chan in seral stages, (3) populations can be depress immediately by a given burn, but increased in th long run, and (4) when regular burning is stopp populations can increase immediately but become depressed in the long run.

The best available information comes from Baker's (unpublished) study which was conducted a park-like loblolly (*Pinus taeda*)-shortleaf pi

(P. echinata) stand that had been winter-burned annually for decades. Burning ceased in March 1967, and plant succession was allowed to proceed unhindered. A live trap census was begun immediately after the last fire, continued for 12 consecutive years, and initiated again in 1986.

Many least shrews (Cryptotis parva), several eastern harvest mice, and a few cotton mice, short-tailed shrews (Blarina brevicauda), and golden mice (Ochrotomys nuttalli) were recorded on the fresh burn. During the first and second years post-burn, herbivores and granivores became ominant [cotton rats, cotton mice, eastern arvest mice, and house mice (Mus musculus)]. Growth of woody cover mixed in with abundant herbs as an important factor in this increase. Shrews insectivores) apparently declined during this eriod, then became rare or absent for the next ix years.

The early brush stage (years three and four) lso supported abundant cotton rats and cotton ice, but eastern harvest mice and house mice did ot persist beyond this stage; the more omnivorous nd arboreal golden mouse began a marked increase. olden mice increased further during the next two rowing seasons and remained common for at least ix years thereafter. Species more fully ependent on groundstory vegetation gradually eclined during this period, but the eastern lying squirrel (Glaucomys volans) became quite bundant after the ninth growing season. The hort-tailed shrew reappeared during years 8 hrough 11 after fire exclusion, probably as a esult of optimal litter structure and arthropod bundance.

Nineteen years after fire was excluded 1986), a few golden mice and many flying quirrels were captured, and gray squirrels Sciurus carolinensis) were often seen (all rboreal species). To date, it appears that the errestrial species and even the semiarboreal olden mouse depend on early post-fire ccessional stages in this forest. Whereas ker's data might apply only to certain pine rests, it serves here to illustrate a basic emise: the majority of small mammals thrive in rly- to midsuccessional habitats which are intained (if not created) by fire, or by some her disturbance that has a similar effect on getation. The relationship between sunlight tensity, lower-level vegetation, and small mmal species should be investigated in other rest types to more fully assess the role of re.

Tree Squirrels.--Burning can have a major pact on tree squirrels. Kirkpatrick and Mosby 981) pointed out that fire significantly grades habitat of squirrels when it is employed fectively to maintain pure pine stands. In such ses the most serious negative factor was thought be the damage to den trees, developing hardwood plings, and mature mast producers. In contrast, ey felt that low-intensity ground fire might ve no adverse effects in squirrel woods other an the destruction of acorns in the duff.

Fire may have a positive influence on squirrel habitat in some situations. For example, it is generally accepted that squirrel population levels depend to a large degree on the supply of acorns; low-growing oak species in the Coastal Plain are dependent on periodic fire for maintenance and for acorn production (Williams 1977). Furthermore, squirrels require certain nutrients that are insufficient in acorns (protein, key minerals). For a balanced diet they also feed on mushrooms (which often increase with burning) or fruits and seeds such as dogwood drupes (a species maintained by fire in many forests).

Population data are very scarce for any squirrel species in pine-dominated forests. Least is known about the ecology of southern flying squirrels. In Baker's study (op. cit.) this secretive species was not captured frequently in a post-fire study plot until about the tenth year when water oaks (Quercus nigra) and other hardwood saplings formed a tall midstory. However, in this same pine forest (Tall Timbers Research Station) flying squirrels are very abundant, even though most of the landscape has been winter-burned annually for over a century. W. Baker (pers. comm.) documented 20 to 30 flying squirrels denning together during winter in a nest box erected in open pine woods. Habitat quality is enhanced by mature live oaks (Quercus virginiana) spaced throughout the annually burned property. Also very abundant in this forest are gray squirrels and fox squirrels (Sciurus niger).

In frequently burned pine-dominated forests, gray squirrels primarily inhabit drains, wet depressions, and upland hardwood islands which get their start where fire misses areas for a few successive years. These hardwood islands develop less frequently on flat terrain than clay hill terrain. For example, on quail plantations in the Red Hills region of southwest Georgia and northern Florida, the spread of hardwoods is a constant problem where old field loblolly and shortleaf pines predominate. Hardwood encroachment advances as lightning strikes and pine beetles gradually kill the large pines while annual winter fires tend to repress pine regeneration. Fire quickly becomes less effective at controlling hardwoods as pine needle cast decreases. Since practically all pine forests on well-drained clay sites, whether in the Coastal Plain or Piedmont, are old-field communities, it is probable that squirrels will be provided for where winter prescribed burning is the sole tool for controlling hardwoods in such forests. Because gray squirrels feed to a large degree on pine seeds, habitat quality could be more stable with parcels of mixed pine-hardwood than in pure hardwood forests where fluctuating oak mast is the only mainstay. However, in Coastal Plain forests where wiregrass is still abundant in the understory, repeated fires suppress hardwoods so thoroughly that gray squirrels are uncommon.

Fire has probably been a determining factor in the niche separation between gray and fox squirrels in the Coastal Plain. Even though both exist in mixed pine-oak forests and feed heavily on acorns, the more competitive gray squirrel dominates locally where the overlap of oak crowns allows tree-to-tree travel through the canopy. The much smaller body size of grays may also have advantage in contending with low ebbs in acorn supplies.

It has been reported that fox squirrels are more abundant where patches of oaks comprise less than 30% of pine-hardwood stands (Hilliard 1979). From long-term studies in longleaf pine forests, Weigl *et al.* (1983) theorized that southern fox squirrels evolved into the largest sciurid in North America (1 kg or larger) through the advantage of traveling long distances to find longleaf pine cone concentrations and the greater ability to handle and tear apart these large cones. This theory together with the fact that fox squirrels are quite clumsy when trying to travel in canopies, and spend a great deal of time foraging for acorns as well as bulbs, seeds, etc. on the ground, would indicate they do best in fire-type pine forests with scattered hardwood inclusions. A lush, grassy groundstory maintained by fire is important as protective cover from predators (Hilliard 1979). The gradual disappearance of this mixture of habitat components has led to a serious population decline of fox squirrels throughout the South.

Rabbits.--The subject of prescribed fire and rabbits in southern forests was reviewed by Hill (1981). He stated, "Most wildlife researchers believe that any planned fire that reduces plant succession to an earlier stage will generally be beneficial to rabbits." The immediate adverse effects of cover reduction are thought to be overridden by improved forage quality and quantity for two or more growing seasons after burning. Hill (1981) also concluded that burn cycles longer than two-year intervals would be less beneficial, but that "any fire is believed better than fire exclusion."

There are important implications that burning helps reduce the parasite burden on rabbits (Hill 1971; Van Rensburg 1971). By combining the findings that rabbit litter size depends on the nutritional quality of forage (Hill 1972) with the numerous data that show light burning increases high-protein herbs (legumes, grasses, etc.) eaten by rabbits, the potential becomes clear for a positive reproductive response to fire. However, since rabbits also feed on certain shrubs and vines (especially during winter) and require thickets for escaping from their many predatory enemies, it would seem that a clean annual burn would be far less ideal than mosaic burning that would leave sizable patches of woody plants. It is also possible that burning a number of scattered parcels periodically during the colder months might provide greenery that would help overcome food shortages. To maintain habitat diversity, Hill (1981) suggested alternating the burning on adjacent plots during a given year.

Furbearers.--There are eight medium-sized mammals classified as fur bearers that live in southern forests. All are highly mobile, terrestrial species--foxes (*Urocyon cinereoargenteus* and *Vulpes fulva*), bobcat (*Lynx rufus*), raccoon (*Procyon lotor*), skunks (*Spilogal putorius* and *Mephitis mephitis*), opossum (*Didelphis marsupialis*), and coyote (*Canis latrans*). There are apparently no references to indicate any direct effect of fire on these mammals, but indirect effects on foods and other resources can be quite important (Hon 1981).

The welfare of major predators--foxes, bobcat, and coyote--depends to a great degree on accessibility to smaller mammals. The benefits fire in maintaining early successional habitats for these prey species was discussed in previous sections. It is also probable that predator efficiency is improved by ground fires (open substrates for quieter stalking and easier captu of prey, concentrating effect on prey in patches missed by fire, etc.). If improved efficiency i a significant advantage, it may be that burning annually provides better stalking grounds than biennial or longer intervals that actually yield the most total prey. This factor might account for a dense bobcat population recorded on a quai plantation where winter burning was conducted annually (Miller and Speake 1978). Furthermore, it has been suggested that, under natural conditions, frequent fires worked together with predators in keeping small mammals in normal population bounds (Komarek 1939).

While terrestrial furbearers all eat small mammals to some extent, other food items are important to various degrees. Insects are prim or secondary food items. Litter dwellers (cert ground beetles, etc.) are often displaced by herbivorous insects (grasshoppers, etc.) after fire; the latter insect group typically constitutes the bulk of insect components of furbearer diets.

Fruits are important in diets of the more omnivorous species (foxes, coyotes, raccoons, opossums). Of the major fruit species, acorns, persimmons (*Diospyros virginianus*), plums and cherries (*Prunus* spp.), and grapes (*Vitis* spp.) can be severely reduced by fire in the short ru However, these woody species require openings establishment, so edges of burns in pine fores may be common regeneration sites for many of th plants. Important berry producers such as blackberry (*Rubus* spp.), blueberry (*Vaccinium* spp.) and gallberry (*Ilex glabra*) produce the fruit a few years after fire pruning. Fire at three-year intervals would optimize fruit production in open slash pine forests (Johnson Landers 1978).

Hon (1981) inferred that burning on a thr year rotation should create desirable furbeare habitat in the southeastern pine region. He a noted that certain fire-sensitive fruit produc should be protected for longer periods. To th suggestions might be added that some upland ar be burned more frequently to maintain grasshoppers, etc. and low vegetation where predators could more efficiently catch prey.

Black Bear.--Black bears ranged throughout the southern pine belt before the build-up of human population centers. Occupied range south of the mountain regions is now restricted to large, relatively inaccessible forests in the Lower Coastal Plain.

Hamilton (1981) synthesized information concerning fire effects based primarily on his bear research in North Carolina and the investigations of other researchers in Florida. He pointed out that periodic winter burning is propitious for production of fruits [dwarf oak, saw palmetto (*Serenoa repens*), etc.] and tender shoots which comprise the bulk of the diet, but advised against summer burning because it can deprive bears of a wide variety of foods. For pocosins, Hamilton (*op. cit.*) suggested that periodic burning (every three to seven years) be restricted to zones between pine-scrub oak sand ridges and Carolina bays or hardwood swamps. Because broad-scale burning temporarily reduces food supplies over large areas and pushes bears into unfamiliar territory where they are quite vulnerable, he recommended burning numerous, small areas throughout bear habitat to create a maze of post-fire stages, and to burn pine-hardwood habitats on a 5-10 year rotation. This recommended frequency might have to be modified depending on soil fertility of a given management area. Planning for juxtaposition of various successional stages seems as appropriate for managing habitat for black bears as it does for the mid-sized omnivores discussed in the previous section. In pocosin country it is critical to schedule prescribed burns when peat soils are saturated to guard against subsurface fire. However, the benefits of careful burning are evident when compared to the destructive nature of wildfires which occasionally ravage through "protected" pocosins.

White-tailed deer.--Most information regarding the effects of fire on deer pertains to habitat influences. Stransky and Harlow (1981) pointed out that burning typically causes several changes: 1) an increase in certain essential nutrients (protein and phosphorus which are generally limiting in the Southeast) and alatability of forage during the first growing eason or longer; 2) initial reduction of leafy biomass, followed by effective increases until rowse grows beyond a deer's reach (above 1.5 m fter about three years); and 3) an initial ecrease in fruit yields of most shrubs, followed y increases in the next three to five years in ome forests or longer-term decreases in others. The overall higher plane of nutrition resulting from fire can improve antler development in bucks and the condition of fawns (Beasom and Springer 981).

Negative effects commonly noted by biologists re the reduction of acorns and a temporary islodging of deer from their home ranges after arge-scale fires. Regular burning favors herbs ver woody browse plants, more so by warm-season han by winter burns. Some of the highly referred forage plants are woody vines which are notably pruned back by fire and may be virtually eliminated by repeated burning of areas with dense deer populations. Therefore, the burning interval and percentage of an area burned each year are major considerations in deer range management.

Since browse plants generally surpass their prime by the fifth growing season after sprouting, deer range might approach optimum condition with a five-year cycle scheduled to burn about 20% per year in small parcels. The conflicting requirements of low browse vs. hard mast supplies would suggest that delineating browse production areas apart from major oak stands would benefit deer. Research on the optimum size and shape of burning units would help refine management schemes. Studies are also needed on effects of small, warm-season burns to see if the resulting succulent growth might better meet the nutritional needs of pregnant does and young fawns.

CONCLUSIONS

The complexity of the foregoing summaries show that any generalization about "how fire affects wildlife" would be tenuous at best. Not only is each wildlife species affected differently, each forest type and local habitat situation reacts differently to a given fire. Cumulative information must be interpreted cautiously.

Even though fire is generally an insignificant direct cause of wildlife mortality, it indirectly influences the abundance and species composition of pine forest wildlife through regulation of lesser vegetation. Most residents are early- or midsuccessional species. Habitation in preclimax stages of today actually reflects a primal dependence on fire--the prevailing disturbance force for thousands of years.

Prescribed burning is perhaps the most under-utilized but valuable tool available to wildlife managers. A critical evaluation of burning is needed before its usefulness can be fully realized in even a single-species plan. If the habitat is decadent then fire may provide benefits quickly, but if the habitat is already in prime condition, fire may set back the targeted species, at least in the short term.

Goal-setting is essential in management with fire. An objective of general wildlife diversity is self-conflicting. But because most species require at least some habitat patchiness, this goal might be approached by blending spot burning with parcels spared from fire for various lengths of time, depending on site fertility and vegetation type. Research is needed for developing recommendations for patch size to accommodate different species. In all cases, the quality of pine sites should be taken into consideration because the richer the site, the greater the probability that increasing numbers of hardwoods will reach fire-resistant size and outstrip the control of low-intensity fires.

The opportunity for "natural community stewardship" in southern pine forests has been foregone for several decades. Attempts to duplicate what anyone might visualize as truly natural should be accompanied by plant ecology research involving variable summer fires together with documentation of resulting gains and losses of wildlife. The trade-offs in choosing one goal over another must be evaluated more closely as managers try to provide for wildlife on dwindling forest lands in the future. The easiest goal--featuring deciduous canopy species--can be reached in pine forests after many years of benign neglect unless a wildfire occurs. The wisdom of taking that course should be closely scrutinized by all decision makers involved in conservation. A better approach for accommodating such species would be to manage for hardwood stands on true hardwood sites.

Management with fire will always require on-the-ground judgment and a thorough knowledge of the requirements of targeted wildlife. Long-term studies of fire-community relationships are needed to help land managers choose the proper burning schemes to reach their objectives.

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Herbicides and Wildlife in Southern Forests[1]

William C. McComb[2] and George A. Hurst[3]

Abstract.--A review was conducted of the literature on the direct and indirect effects of herbicide application on forest wildlife. Herbicides vary in toxicity to wildlife, but acute toxicity to most species from most herbicides under normal field conditions is unlikely. Effects on terrestrial vertebrates of repeated applications of herbicides over long time periods or repeated exposure to contaminants of herbicides (such as occurred with dioxin in 2,4,5,-T) is unknown. Herbicide application alters habitat composition and structure thereby resulting in differential response to herbicide-treated stands by terrestrial vertebrates. Application of herbicides in most southern forest situations may result in short-term changes in the abundance of some terrestrial vertebrates. Herbicide use in mature forest for TSI will promote canopy gaps and understory biomass production, while use in young clearcuts will temporarily reduce understory biomass. Published data describing direct effects of herbicide application on wildlife reproduction and survival and on herpetofaunal response to habitat changes are lacking.

INTRODUCTION

Vegetation management using herbicides is widespread in southern pine and hardwood forests. Herbicides are used in pine forests to release pine seedlings from competing hardwood regeneration and to prepare sites for planting. Use in hardwood stands includes timber stand improvement (TSI), right-of-way management and wildlife habitat improvement. During 1975, approximately 11 million kg (25 million lbs) acid equivalent (a.e.) of 2,4-D (mention of trade names does not imply endorsement by the Kentucky and Mississippi Agricultural Experiment Stations) was used in the U.S. in non-agricultural crop situations, including forestry (U.S. Forest Service 1984). The U.S. Forest Service (1984) provided use and application rate information for herbicides used on Forest Service lands in 1981 and 1982. Approximately 100,000 ha (250,000 acres) were treated with approximately 225,000 kg (500,000 lbs) a.e. of 8 herbicides (atrazine, 2,4-D, dalapon, glyphosate, hexazinone, trichlopyr, sulfometuran methyl, and picloram) each year. These herbicides (except atrazine and dalapon) account for approximately 90% of the herbicides used in southern forests (C.S. Metcalfe, pers. comm.); they are applied aerially or broadcast as pellets in most situations except TSI where individual trees or stumps are injected.

Herbicides in an ecosystem can: (1) degrade on site, (2) be transported to a new site and degrade, or (3) bioaccumulate (U.S. Forest Service 1984). Degradation rates for most herbicides have been estimated under a variety conditions and vary widely on different sites. For instance, picloram has a half-life of approximately 1 month on moist sites and up to years on arid sites. Glyphosate and dalapon ar rapidly degraded by soil micro-organisms; 2,4-D has a half-life of 1 month or less but hexazino has a half-life of from 1 to 6 months (U.S. Forest Service 1984).

Herbicide transport is generally either by wind, water or herbivores. The solubility and persistence of a herbicide in water are critica to toxicological effects on aquatic organisms. There is considerable variation among herbicide in solubility and degradation in water (U.S. Forest Service 1984). Generally, herbicides us in forest management rarely reach high concentr tions in aquatic systems.

The degree of bioaccumulation in vertebrat is dependent upon solubility in organic solvent and water, rate of excretion and rate of metabo lism. Chemicals vary greatly in their accumulative nature. Herbicides, their metabolites a their contaminants (such as dioxin) probably va in bioaccumulation capacity.

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HERBICIDE EFFECTS ON WILDLIFE HABITAT IN UPLAND HARDWOODS

Herbicide use indirectly affects two vege- ive components of wildlife habitat: composi- n and structure. These two components are nly interrelated; a change in habitat compo- ion will likely change habitat structure.

itat Composition

Some wildlife foods can be adversely ected by herbicide application, and some can enhanced by it. Hard mast species composi- was adversely affected by broadcast appli- on of picloram in upland hardwoods, but soft species and browse species composition and nance increased 4 years after application omb and Rumsey 1981). Some plant species adversely affected by picloram: grasses ceae), New Jersey tea (*Ceanothus* *icanus*), dwarf cinquefoil (*Potentilla* *densis*), blackgum (*Nyssa sylvatica*), and afras (*Sassafras albidum*). Integration of life habitat management into TSI is possible njection of low quality stems competing for n space with oaks (*Quercus* spp.), hickories *ya* spp.) and other mast-producing species omb and Rumsey 1983a). Increased light tration into the canopy will allow an in- se in crown size and hence a greater likeli- of increased mast production (Goodrum et 1971). Simultaneously, killing of undesir- trees allows light to strike the forest r which should stimulate understory pro- ion for browse, or (if the canopy gap is e enough) soft mast production by shrubs.

tat Structure

Foliage structure will be altered after icide application for TSI in three ways: 1) educing overstory cover and increasing cover ower foliage levels over time, 2) by in- sing snag (dead tree) availability, and 3) tering the litter layer on the forest r. Rate and method of herbicide application affect stand structure. Heavy broadcast cations in mature hardwoods or tree injec- of residuals after clearcutting will result gh snag density (McComb and Rumsey 1981, on et al. 1983), dense understory cover 1 years after application (McComb and Rumsey , low overstory cover, and rapid decompo- n of the leaf litter layer (Gottschalk and 1979). As a result of these structural es, the forest floor likely will be hotter rier than untreated sites until understory increases the shade. Light applications oadcast herbicide or TSI likely will result increase in foliage height diversity by ing increased foliage development of sub- y layers. Effects on the leaf litter layer be minimal. Snag density would increase rovide foraging substrate for bark-foragers ek 1985). Hardwood snags created by cide-injection have shown the potential for acceptable nest substrates for cavity- rs (Conner et al. 1983, McComb and Rumsey 1983a, Dickson et al. 1983, and McPeek 1985); herbicide-injected conifers may not be suitable nest substrates for cavity-nesters (Bull and Partridge 1986) but McPeek (1985) reported higher use of herbicide-killed pine snags than of hardwood snags by bark-foraging birds. Longevity of herbicide-created snags is approximately 4 to 8 years for 50% of the snags created (Dickson et al. 1983, McComb and Rumsey 1983a). Although herbicide-created snags in young stands are ephemeral, they are important to bird use of a stand (Warren et al. 1984, Dickson et al. 1983). As snags fall, they become logs that provide habitat for forest floor fauna.

HERBICIDES AND SOUTHERN PINE SILVICULTURE

Herbicide use in southern forests is most frequently in association with production of southern yellow pines (*Pinus* spp.), simply because of the scale of pine management versus hardwood management in the South. Pine plantations are a prevalent and growing habitat type in the South, and herbicides have become an integral part of plantation establishment and management (Miller 1984). Research on several aspects of plantation management have been conducted throughout the South (Harris et al. 1975, Hurst and Warren 1980). However, information on the more recent uses of herbicides in plantation management as they affect wildlife habitat is generally lacking (Morrison and Meslow 1983). Some general and specific results of research being conducted on the lower Coastal Plain of Mississippi and Alabama are presented as indicators of the relationships of herbicides to some wildlife habitat conditions.

Site Preparation: Broadcast Herbicide and Burn

After clearcutting mature forests (often mixed pine-hardwood), pelletized herbicide is applied to kill residual stems. A hot, broadcast burn is then conducted in late summer; pine seedlings are planted the following winter. This new method is similar to the mist-blow (2,4,5,-T), following inject (2,4-D), and burn method.

Conversion of the mature forest to a pine plantation has drastic effects on habitat for some wildlife species such as squirrels (*Sciurus* spp.), but the early successional stage created can represent habitat improvement for other species (Johnson et al. 1974, Buckner and Landers 1980). Hard and soft mast-producing trees are replaced by a herb-dominated (forb, grass, vine, and shrub) community. Soft mast production by *Rubus* spp. increases with plantation age and peaks in 5 years (Campo and Hurst 1980).

The open nature of the first growing season is too harsh for some vertebrates but is excellent for birds such as mourning doves (*Zenaida macroura*) and bobwhite quail (*Colinus virginianus*) that feed on the ground. During the second growing season the vegetation becomes more dense, affording food (forage) and cover for more wildlife species.

Preferred white-tailed deer (*Odocoileus virginianus*) forage (grasses, forbs, vines, and woody plants) averaged 385 kg/ha (350 lbs/ac) in late summer of the first growing season after herbicide treatment (mist-blow and inject) and burning, whereas mature mixed forests averaged only 75 kg/ha (68 lbs/ac) (Hurst and Warren 1981). Deer forage increased to over 550 kg/ha (500 lbs/ac) by year 5 and then declined as canopy closure occurred.

Small mammal populations are generally low in mature, mixed forests but increase in early seral stages on pine plantations. Perkins (1973) found the highest capture/effort index (24.8/100 trap nights) for small mammals (mostly cotton rats [*Sigmodon hispidus*]) on pine plantations prepared by herbicides and fire. Raptors and medium-sized predators (*Lynx rufus*) were observed frequently in these plantations. Small mammal populations declined at canopy closure (5-6 years).

Logging debris, whips, and snags are a major component of herbicide-treated sites; their addition to the structure provided by rapidly growing herbaceous vegetation improves avian habitat. Darden (1980) found herbicide-treated plantations to have greater bird species diversity and higher relative abundance than plantations that were mechanically site prepared. A total of 47 species was observed with 26 nesting in the first year in mist-blown, injected, and burned plantations (Perkins 1973). Warren et al. (1984) reported the highest cavity-nesting bird relative abundance (695/100 ha; 278/100 ac) to be in 4-year-old plantations prepared by herbicides and fire. Snags usually deteriorate within 8 years.

Site Preparation: Mechanical and Herbicide

A relatively new practice is to follow intensive mechanical site preparation with a broadcast aerial application, either preplant or postplant, of hexazinone (0.6-0.9 kg/ha; 0.5-0.8 lb/ac) for competition control. Mechanical site preparation (shear, rake, burn, disk, bed) reduces the hardwood component, and the herbicide temporarily controls grasses, sedges, and broadleaf weeds.

Such intensive mechanical site preparation destroys all potential snags and most logging debris; during the first year's growth there is little vegetative cover, but remaining plants exhibit rapid growth rates because of little or no competition. Burned windrows have luxuriant herbaceous vegetation. The sparsely vegetated plantations are excellent winter habitat for mourning doves, American robins (*Turdus migratorius*), and bobwhite quail because 2 plant species, dove-weed (*Croton capitatus*) and pokeweed (*Phytolacca americana*), are tolerant to the herbicide and produce a large number of seeds and fruit.

Preferred deer forage in late summer of the first growing season averaged only 99 kg/ha (90 lbs/ac) on mechanical and herbicide-treated p and over 550 kg/ha (500 lbs/ac) on plots with only mechanical site preparation. During the first winter, deer forage averaged only 4.4 k (4 lbs/ac) on herbicide-treated plots and abo 110 kg/ha (100 lbs/ac) on mechanically-treate plots (Copeland 1986, Blake 1986a). Vegetati on the plantations increased markedly during second growing season with 1,145 kg/ha (1,041 lbs/ac) of deer forage in late summer and 67 kg/ha (61 lbs/ac) in late winter on plots tha received both mechanical and herbicide treatments. Deer forage declined the third y but still averaged 582 kg/ha (529 lbs/ac) (Copeland and Hurst 1986).

Habitat conditions for rabbits (*Sylvilag* spp.) were poor the first year because of the sparsity of vegetation but conditions improve the second year. Both forage production and lateral and overhead cover greatly increased during the second year (Copeland 1986).

Darden (1980) found that plantations prepared by the intensive mechanical method had lowest number of bird species and densities. Perkins (1973) reported only 18 species usin comparatively barren conditions during the f year after intensive mechanical site pre-para (no chemicals). By the third year 27 species observed.

Site Preparation: Mechanical and Broadcast v Banded Herbicide

A modification of the above site preparation method is to aerially broadcast a pelletized herbicide (hexazinone) after intensi mechanical site preparation, or to apply a l herbicide (hexazinone), back-pack style, to the top of the beds (mounds). The latter me is more cost effective and should leave bett habitat conditions in young plantations.

Total plant biomass, excluding pine seedling/sapling weight, was significantly l on broadcast-treated plots and banded plots on control (no herbicide) plots in the firs growing season. Banded plots averaged 450 k (409 lbs/ac) more biomass than broadcast pl Preferred deer forage biomass was only slig higher on banded plots than on broadcast-tre plots. At the end of the second growing sea there was no significant difference in tota plant biomass or deer forage between the 2 treatments or the controls. The herbicide short-term effect on plant growth (Blake 19 The number of plant species on the broadcas treated plots was about half that found on control plots the first year but equal to c trol plots the second year (Blake 1986b).

Pine Release: Herbicides

Another major use of herbicides is to lease pine saplings from hardwood competiti plantation age 4-8 years. An aerial or gro application is used.

Effects of an aerial application of a herbicide for pine release were studied in west-central Alabama and east-central Mississippi at plantation ages 4 and 5 years, respectively. In each case, significantly more grass, forb, vine, and woody preferred deer forage was found on the treated, than on control plots (922 vs. 609 kg/ha and 965 vs. 519 kg/ha; 838 vs. 554 lbs/ac and 877 vs. 472 lbs/ac). Forbs accounted for 55-63% of the total forage (Hurst and Warren 1986). Killing the hardwood shrubs released forage and seed-producing plants.

Pine plantations in the South are usually dense at age 4-6 years, and the herbicide application may improve cover conditions increasing accessibility to some species. Habitat was improved for ground-feeding birds such as bobwhite quail, mourning dove, and wild turkey (Meleagris gallopavo). Nesting habitat for birds that nest in low to tall shrubs remained adequate. Releasing pine seedlings will cause the canopy to close and habitat conditions to change rapidly.

Control of competing hardwood shrubs (suckers and sprouts) can also be accomplished by spot spraying or back-pack spraying (foliar) hardwood stems. This technique is used when few hardwood stems exist in plantations. This method will result in some release of herbaceous plants but on a smaller scale than occurs with a total site application. An important feature of the individual stem system is the opportunity for the field crew to selectively leave (not spray) important food plants for wildlife Vaccinium spp., Callicarpa spp., Rhus spp., ornus spp.).

imber Stand Improvement (TSI): Herbicides

Herbicides have long been used to kill inject) undesirable stems or species of trees a mixed pine-hardwood forest to release the ne component. This practice alters the habi- at by reducing or eliminating hard mast (oaks d hickories) and soft mast (Nyssa spp., ospyros spp., etc.), by reducing den trees and altering vegetative structure and diversity. oduction of pine seeds, an excellent wildlife od, would probably increase.

The injected trees become snags, providing rches, foraging sites, and cavities for a ort time. Fallen trees provide micro-habitats r some ground-dwelling vertebrates. By kill- g most of the hardwoods, small openings are eated and forage production by grasses, forbs, nes, and woody shrubs increases. Fruit pro- ction by tall and low shrub species (e.g. ccinium spp.) and vines (Lonicera spp. and bus spp.) increases. With more vegetation on forest floor, cover conditions will improve rabbits and some other mammals.

General Remarks: Herbicides in Pine Plantation Management

Use of herbicides in pine plantation management is but a small part of the overall scheme. Many factors and practices dictate habitat conditions, such as plantation size, shape, and situation (juxtaposition), age class distribution, seedling spacing, and seedling survival. Intermediate silvicultural practices, precommercial and commercial thinning, controlled burning, fertilizing, and pruning greatly affect habitat conditions. Retention of streamside management zones, hardwood leave strips, and special areas (seeps, bogs, etc.) are major practices.

Use of herbicides to control grass and herbaceous weed competition is increasing, but the effects are temporary. Generally plant biomass, plant species composition, and herbivore forage are equal to control (not-treated) sites by the second growing season after treatment. Use of herbicides to kill competing hardwoods, either as mature trees (TSI) or "brush" in plantations, eliminates the majority of the hard and soft mast producers. However, hardwoods have no "future" in short-rotation plantations; controlled burning will be used frequently to top-kill hardwoods, so hard mast producers will not have an opportunity to produce. The management scheme will be directed to producing forage and soft mast from shrubs and vines. Pine seed production should be quite high in intensively managed plantations grown on sufficiently long rotations.

With or without herbicides, habitat conditions in pine plantations change rapidly. If the herbicides are successful, pine seedling and sapling growth rates are increased and the rotation is shortened, hastening changes in habitat conditions. With faster pine tree growth the manager can begin thinning and burning practices at a younger plantation age to improve habitat conditions for some wildlife species (Owen 1984).

EFFECTS OF HERBICIDE APPLICATION ON MAMMALS

Toxicological information on mammals is, to a large extent, limited to tests conducted on white lab rats (Rattus norvegicus) (Table 1). Hudson et al. (1984) summarized toxicological tests on a variety of organisms, but they only included mule deer (Odocoileus hemoinus), domestic goat (Capra hireus) and domestic ferret (Mustela putorius) with rats in their tests on mammals. The only herbicides tested on mule deer were 2,4-D with an LD_{50} of 400-800 mg/kg (N=3), a dose similar to that reported for rats (Table 1), and silvex with an LD_{50} of 400 mg/kg (N=1), less than that reported for rats. Obviously, sample sizes for mule deer are low and extrapolation from one species to another is unwise, but it seems that some herbicides are potentially more toxic to wildlife than others. Toxicity of dalapon and hexazinone to rats is considerably less than the toxicity of 2,4-D and paraquat

Table 1.--Toxicity of selected herbicides to vertebrates

Herbicide	Species (LD_{50};mg/kg)				
	Mallard[1]	Pheasant[1]	Bobwhite[1]	Bluegill[1] (LC_{50},ppm)	Rats[2]
Alachlor (Lasso)[3]	>2,000	-	-	-	
Amitrole (Amizol)	>2,000	5,000	-	300-1200	5,000
Atrazine (AA trex)	>2,000	>2,000	>5,000	6-24	1,750
Balan (Balfin)	>2,000	-	-	-	-
Butylate (Sutan)	>2,000	-	-	-	-
Chloroxuron (Norex)	>2,000	-	-	-	-
Cynazine (Bladex)	>2,400	-	445	-	-
2,4-D	>2,000	472	>5,000	0.6-11	370
Dalapon	>5,000	-	<5,000	105-1,000	5,000-10,
Dichlobenil (Casoron)	>2,000	1,189	-	6-12	-
Dinoseb (Premerge)	27.0	26.4	-	-	-
Diuron (Diurex)	>2,000	-	-	7-9	-
DNOC (Selinon)	22.7	31.8	-	-	-
Endothall (Des-I-Cate)	229	< 198	-	-	-
Fluometuron (Lanex)	>2,000	-	-	-	-
Fluorodifen (Soyex)	-	>2,000	-	-	-
Glyphosate (Roundup)	>4,000	-	>4,000	2-160	4,300
IPC-400 (Propham)	>2,000	-	-	-	-
Paraquat Dichloride (Weedol)	199	-	-	8-19	150
Picloram (Tordon)	>2,000	>2,000	-	10-30	8,200
Planavin (Nitralin)	>2,000	-	-	-	-
Potassium Azide (Azide)	22.8	15.1	-	-	-
Silvex (Garlon)	>2,000	-	-	0.7-0.9	630-729
Silvisar-510 (Arsan)	>2,400	-	-	-	-
Sodium Arsenite (Kill-All)	323	386	-	21-42	-
2,4,5-T	>2,000	500-1,000	-	8-47	-
TBA (Benzac)	>2,000	1,000	-	-	-
TCDD (Dioxin, contaminant of 2,4,5-T)	0.108	-	.015	-	-
Terbutryn (Igran)	>2,000	>2,000	-	-	-
Trifluralin (Triflurex)	>2,000	>2,000	-	47-70	-
Velpar (Hexazinone)	-	-	2,258	100-500	1,500-5,

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[1] from Hudson et al. (1984), U.S. Forest Service (1984) or Johnson and Finley (1980).
[2] from Walstad and Dost (1984).
[3] alternative common name presented parenthetically.

dichloride to rats. The U.S. Forest Service (1984) estimated dermal exposure of herbicides to deer (Odocoileus spp.) of 0.101 mg/kg and to rabbits of 0.403 mg/kg for each 1.1 kg of active ingredient herbicide applied per ha (1 lb/ac.). At recommended rates of application, no herbicide for which data are presented in Table 1 for rats would reach LD_{50} toxicity levels through dermal exposure.

Herbivores also may be exposed to herbicides by ingestion of herbicide-contaminated plant material. Oral exposure rates of 1.4 and 1.1 mg/kg for each pound (0.45 kg) of active ingredient of herbicide have been calculated for deer and rabbits, respectively (U.S. Forest Service 1984). Even at this rate, it is unlikely that most commonly used herbicides would be toxic to most herbivorous mammals under most circumstances, unless the herbicide bioaccumulates.

Average application rates for commonly used herbicides range from 1.1-5.6 kg/ha (1-5 lbs/acre) active ingredient. It probably wo be safer to mammals to use relatively less toxic herbicides such as amitrole, dalapon, picloram and hexazinone than paraquat dichlo or 2,4-D where feasible. Norris (1981) foun traces of phenoxy herbicides in some wildlif species (0.01 to 10 mg/kg) exposed to field herbicide application.

Sullivan and Sullivan (1981) concluded a forest application 2.2 kg/ha (2 lb/acre) o glyphosate in Douglas-fir (Pseudotsuga menzi had no adverse effects on reproduction, grow or survival of deer mice (Peromyscus maniculatus). Johnson and Hansen (1969) reported similar effects of 2,4-D on deer mice Indirect effects of herbicide application on mammal abundance have been reported in sever forest situations. McComb and Rumsey (1982) reported small mammal abundance increasing 100% 4 years following broadcast application of picloram in upland hardwoods, but a 200% increase was recorded on clearcut plots. The addition of logs, stumps and understory cover contributed to the habitat quality of the treated site. Similarly, Kirkland (1978) reported a 100% increase in small mammal abundance 1 year after 2,4,5-T application in Appalachian hardwoods. McCaffery et al. (1981) reported more small mammals from picloram-created clearing edges than in the center of the clearings or in the adjacent woodland in northern hardwoods. Based on these studies it seems that field applications under normal conditions of picloram, 2,4-D or glyphosate improves habitat for most small mammal species for a few years; species adversely affected by treatment are reduced in numbers probably because of habitat changes and not because of herbicide toxicity.

Application of herbicide in a mature stand will likely increase browse availability; application of herbicide in a young stand will reduce browse availability for a few years. Krefting et al. (1956) successfully used herbicides to promote sprouting of mountain maple (Acer spicatum) for deer browse in northern hardwoods. McComb and Rumsey (1981) reported an increase in available browse in upland picloram-treated areas. Hurst and Warren (1980) reported a similar response by some woody plants in 5-year-old pine plantations in Mississippi; but overall, browse availability was reduced on this site by herbicide (2,4,5-T) application. Easley (1977) reported short-term reduction in woody browse for deer following 2,4,5-T application in outhern pine plantations.

EFFECTS OF HERBICIDE APPLICATION ON BIRDS

More information is available on toxic ffects of various herbicides on birds than on ammals, primarily because of the frequent use f mallard ducks (Anas platyrhynchos) as test ubjects (Table 1). Pheasants (Phasianus olchicus) and bobwhite quail also are frequently used in LD_{50} tests. Results for most erbicides tested on all 3 species were consistent, but with some exceptions. Tests of ,4-D showed higher toxicity on pheasants than n mallards or quail. Cynazine was more toxic o quail than to mallards. Frequently-used erbicides such as atrazine, glyphosate, picoram, hexazinone, and dalapon seemed relatively ontoxic compared with dinoseb, ONOC, and potassium azide. All toxicity tests reported in able 1 were conducted under laboratory onditions.

Field studies of bird response to herbicide pplication largely describe bird response to hanging habitat suitability. Dickson et al. 1983) compared bird use of clearcuts with and ithout 2,4-D-created (injected) snags and concluded that these herbicide-created snags inreased the diversity and density of birds using the clearcuts. Warren et al. (1984) reached similar conclusions regarding snags created by spraying with 2,4,5-T and by injected 2,4-D amine. McPeek (1985) recorded bark-foraging bird use of picloram-killed snags in mature Appalachian hardwoods, but she did not detect any increase in abundance or diversity of birds on the TSI site. Snags on her site had not decayed to the point of being good nest sites. McComb and Rumsey (1983a) and Conner et al. (1983) indicated that picloram-killed and 2,4-D-killed trees respectively were potential nest sites for cavity nesters, but girdled trees remained standing longer than herbicide-injected trees. Bull and Partridge (1986) reached similar conclusions in western forests. Broadcast picloram herbicide in upland hardwood forests increased winter bird density over untreated mature hardwoods after 4 years (McComb and Rumsey 1983b). Breeding bird diversity was higher on herbicide-treated plots than on untreated hardwood plots, probably in response to increased understory and midstory strata representation after removal of some overstory trees (McComb and Rumsey 1983b). McCaffery et al. (1981) reported similar findings in picloram-created clearings in Wisconsin. Morrison and Meslow (1984a, 1984b) investigated the effects of 2,4-D and glyphosate application on bird use of clearcuts in western forests. In both studies, herbicide altered the habitat structure resulting in short-term changes in use of the area by some bird species. Savidge (1978) and Beaver (1976) reported similar differential responses of bird species to 2,4,5-T application in a Jeffrey pine (Pinus jeffreyi) plantation. We could find no field studies examining the effects of herbicide application on reproductive success and survival of birds.

Little information is available specifically on effects of herbicide application on habitat of game birds. Hurst (1981) discussed the effects of intensive pine plantation management on wild turkey habitat and he concluded that intensive pine management, including use of herbicides, can provide acceptable habitat for turkeys. Use of picloram herbicide to create clearings in mature hardwoods of central Appalachia resulted in ruffed grouse (Bonasa umbellus) use of 4-year-old treated plots (McComb and Rumsey 1983). McCaffery et al. (1981) reported high grouse use of herbicide-created clearings during the fall in Wisconsin. Use of herbicides to create openings in mature forest for grouse would seem to be particularly feasible in the extensive forest and rugged topography of the southern Appalachians.

EFFECTS OF HERBICIDE APPLICATION ON HERPETOFAUNA AND FISH

Toxicity information is largely lacking for herpetofauna. The U.S. Forest Service (1984) summarized LC_{50} tests for a variety of aquatic organisms and reported concentrations of 200-350 ppm 2,4-D resulted in 50% mortality of tadpoles of 3 non-native anurans. Atrazine concentrations of 0.4 to 50 ppm for tadpoles of American toads (*Bufo americanus*), bullfrogs (*Rana catesbiana*), leopard frogs (*R. pipiens*) and pickerel frogs (*R. palustris*) were also reported (U.S. Forest Service 1984). No toxicity data on terrestrial forms could be found.

Indirect effects of herbicide application on herpetofauna would result by changing the forest floor microclimate and altering the availability of food. Most amphibians and many reptiles are moisture sensitive so a decrease in the canopy cover would allow direct sunlight to penetrate to the forest floor thereby modifying the microclimate. Effects of microclimate modification might be offset by increased availability of invertebrate prey. Research is needed to determine the response of herpetofauna to herbicide application.

Johnson and Finley (1980) tested a variety of pesticides for toxicity on fish. Herbicides varied in toxicity to bluegills (*Lepomis macrochirus*) from relatively toxic compounds such as silvex and 2,4-D to relatively non-toxic compounds such as dalapon and amitrole. All studies are laboratory studies and field response of organisms to herbicides could be different. If use of herbicides in silvicultural practices is at or below rates specified as permissable in forest streams (Newton and Norgren 1977), it is unlikely that acute toxicity to most aquatic organisms would result. A review of indirect effects of herbicide application on aquatic organisms is beyond the scope of this paper.

SUMMARY

The effects of herbicide application on wildlife habitat are usually ephemeral. Herbicide use at normal, recommended rates of application would not usually result in acute toxicity of most vertebrates, but herbicides vary considerably in toxicity to birds, mammals, and fish. Effects on terrestrial vertebrates of repeated applications of herbicides over long time periods or repeated exposure to contaminants of herbicides (such as occurred with dioxin in 2,4,5,-T) is unknown. Field studies of herbicide effects on wildlife are generally of indirect rather than direct effects.

Indirect effects of herbicide application on wildlife is through alteration of habitat. Plant species composition in a stand will be altered depending upon the herbicide used and the method of application. Application of herbicides in most southern forest situations may result in short-term changes in the abundance of some terrestrial vertebrates. Herbicide use in mature forest for TSI will promote canopy gaps and understory biomass production, while use in young clearcuts will temporarily reduce understory biomass. Herbicide use in pine stands to control hardwood competition will reduce the tree species richness and alter structure to increase habitat quality for some species while decreasing quality for others.

Additional research should be conducted on herbicide application effects on reproduction and survival of wildlife under field conditions. Research is also needed regarding both direct and indirect effects of herbicide application on herpetofauna.

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Riparian Zones and Wildlife in Southern Forests: the Problem and Squirrel Relationships

James G. Dickson and Jimmy C. Huntley

Abstract.--Mature woody vegetation along intermittent streams is often retained when upland stands are harvested and are planted to pine. These riparian zones bisecting pine plantations reduce non-point pollution and enhance wildlife habitat. Riparian zones are productive of forage and hard and soft mast, provide habitat diversity, function as habitat corridors, and serve as limited mature forest habitat. Studies are underway to assess the relationships of size and composition of riparian zones to populations of deer, squirrels, wild turkeys, fur bearers, small mammals, breeding and wintering birds, and reptiles and amphibians. In eastern Texas, squirrels were abundant in riparian zones wider than 55 m but were rare in riparian zones narrower than 40 m. Studies of the other vertebrate groups continue.

RIPARARIAN ZONES

In the South, many mature pine and mixed
-hardwood stands are being cut and replaced
ine (*Pinus* spp.) plantations. In 1986, 9% of
midsouth timberland is planted pine, up from
years ago, and this does not include stands
ted to pine but dominated by hardwoods
dsey and McWilliams 1986). A large variety
quantity of herbaceous and woody vegetation
fruit in young pine plantations make them
habitat for many species of wildlife.
e-tailed deer (*Odocoileus virginianus*), cot-
rats (*Sigmodon hispidus*), cottontail rabbits
vilagus floridanus), and many birds fare well
oung clearcuts. But wildlife habitat for
species deteriorates after 7 to 10 years
pine canopies close and shade out
rstories of non-pine vegetation.

When timber is harvested, mature forest
tation along permanent and intermittent
ams bisecting upland sites may be retained to
ce soil erosion and to enhance wildlife habi-
These areas of hardwood or mixed pine-
woods, called stringers, streamers,
amside management zones, or riparian zones
, throughout pine plantations create habitat
rsity and edge, which are important to many
ies of wildlife. They serve as travel corri-
for animals between mature stands and can
maintain genetic flow between potentially isolated populations in adjacent mature stands, thereby helping to maintain population genetic viability. The zones also provide limited habitat for species associated with mature forests, such as pileated woodpeckers and large carnivores. Nesting sites, food, and cover probably are increased for many species of wildlife. Hard and soft mast are produced by the residual trees, and nesting and foraging sites are available in the shrub and canopy vegetation. In Mississippi (Warren and Hurst 1980) and in eastern Texas (McElfresh et al. 1980), squirrel (*Sciurus* spp.) use of RZ was much higher than in adjacent upland stands. Hardwood drains along intermittent streams in RZ usually have fertile soils that support a luxuriant growth of vegetation, producing high yields of a variety of forage and mast and also providing escape cover for deer (Halls 1973). Studies have shown that floodplain forests downstream from RZ support more birds than upland pine stands (Dickson 1978, Stauffer and Best 1980), probably due to their greater vegetative structural diversity. There are also a large variety and an abundance of birds along forest edge (Strelke and Dickson 1980). Retention of mature vegetation along permanent and intermittent streams in clearcuts has been recommended for deer, wild turkeys (*Meleagris gallopavo*), squirrels, and song birds. In the South, the retention of RZ in clearcuts is policy for the USDA Forest Service and several large industrial forest landowners.

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script.

THE PROBLEM

Quantitative data on effects of RZ on wildlife populations are insufficient to enable wildlife managers to justify the retention of RZ in land-use plans on a biological and economical basis. For informed decisions, landowners need to know--What are the differences in wildlife populations in areas with RZ and areas without RZ, and what are the relationships of RZ width and vegetative composition to wildlife abundance? The Wildlife Habitat Laboratory, Southern Forest Experiment Station, USDA Forest Service, is conducting research to help answer these questions by assessing the impact of presence, vegetative composition, and extent of RZ on various segments of the wildlife community. The purpose of this paper is to provide a background on the nature of RZ in the southern forests, discuss the approach and techniques for our research, and present current information on the squirrel phase of the study.

STUDY AREAS AND METHODS

Nine recent clearcuts in East Texas 2-4 years old and 49 to 121 ha in size were selected for study. Selection of the 9 nine areas was based on similarity of topography, soils, vegetation, and surrounding land use. All areas, which had been previously vegetated by second growth pine-hardwoods, were recently clearcut, mechanically site prepared, planted to loblolly pines (Pinus taeda), and traversed by RZ. Mature pines had been harvested from some of the RZ. All plantations were on upland sites, and RZ were along first-and-second order intermittent streams. Pines were generally 0.5 to 1.5 m high. The plantations were dominated by hardwoods, pines, and other woody and herbaceous vegetation. Oak (Quercus spp.) and sweetgum (Liquidambar styraciflua) sprouts, Callicarpa americana, Rubus spp., and Rhus spp. were abundant. Dominant overstory vegetation in RZ included southern red oak (Q. falcata), white oak (Q. alba), post oak (Q. stellata), sweetgum and American beech (Fagus grandifolia).

Assigned treatments were RZ of 3 widths: narrow (< 25 m wide), medium (30-40 m), and wide (> 50 m). Three replications of each treatment were applied. Four sample transects (200 m each) were established in each of the 9 study areas--2 in each RZ and 2 in each adjoining pine plantation. Along each transect, understory, midstory, and overstory vegetation was sampled from 4 points on each transect. Also hard mast is being sampled from visual estimates in tree canopies, and then adjusted by collection in barrels each fall.

The vertebrate community is being sampled by various means. Deer tracks are being counted on plots in RZ and plantations during the fall and spring. Scent stations baited with bobcat urine and fish oil are used to survey furbearers each fall and winter. Small mammal abundance is being determined from live trapping and marking each winter. Bird censuses from transects during winter and the breeding season are being conducted. Reptiles and amphibians in RZ and on plantation slopes are being surveyed by visual counts, inspection of artificial covers, captur from drift fences and funnel traps, and by inte sive searches each spring. Wild turkey use of is being determined supplementally by radio telemetry. The study of squirrels in RZ has been completed and is presented here.

SQUIRRELS

Gray squirrels (Sciurus carolinensis) and fox squirrels (S. niger) are sympatric througho most of the eastern United States (Hall 1981), but favor different habitat types. In eastern Texas, the fox squirrel is more numerous in upland forests, and the gray squirrel is more numerous in bottomland hardwood forests. Both species occur along small drainages with hardwoods and in eco-tones between bottomland hardwoods and the surrounding pine uplands.

Suitable squirrel habitat is lost when old forests are clearcut and converted to even-age pine plantations. But RZ in clearcuts are beneficial to squirrels. In east-central Mississippi, RZ along permanent streams and varying in width from 40 to 141 m had greater squirrel densities than mature pine-hardwood forests (Warren and Hurst 1980). Gray squirrel density was highest in RZ with an average width of 100 m in bottomland sites. In East Texas, gray squirrels used the RZ that were retained i slash pine (Pinus elliottii) plantations (McElfresh et al. 1980). The Texas researchers suggested that RZ 50 to 100 m wide that connect adjoining bottomland forests should provide adequate habitat for squirrels and that additional research would be needed to refine this estimat of necessary width.

The objective of our study was to determine the effect of RZ width on squirrel abundance. Squirrel abundance was estimated with time-area counts (Goodrum 1940) on 2 replications in 1984 and all 3 replications of treatments in 1985 fr observation points at least 100 m apart in each RZ. Observation time at each point was 20 minutes, as recommended by Bouffard and Hein (1978). All counts were completed between 0700 and 1030 hours in mid-to-late September, prior to squirr hunting season. In each RZ, 3 counts by different observers were conducted from 4 observation points for a total of 12 observation periods. One additional count was taken at the edge of the RZ and adjacent plantation to determine squirrel use of plantations. The number o squirrels seen during these 4 hours of observation for each RZ was used to measure squirrel abundance. Squirrel densities based on average detection distances were not calculated.

Squirrel leaf nests were counted in January February 1985 for another index of squirrel abu dance. In each RZ, all nests that occurred in 200 by 80 m transects and that appeared to have been constructed in the prior year were counted.

During both years in the time-area counts, squirrels were observed regularly in wide, very arely in medium, and never in narrow RZ. In 984, a total of 12 squirrels were observed on ide, 1 on medium, and 0 on narrow RZ. In 1985, ith the sample increased by 50%, there were 12, , and 0 squirrels on wide, medium, and narrow RZ espectively (Table 1). Leaf nest density was lso much greater in the wide RZ, 55 nests were ounted on wide, 7 on medium, and only 1 on arrow RZ. Time-area counts and leaf nest denities indicated that squirrels were permanent esidents in only the 3 wide RZ, which averaged 3, 73, and 55 m in width. The 73-m-wide RZ had he greatest squirrel abundance in both years and he greatest density of leaf nests. This RZ also ad numerous large American beech and loblolly ine trees, which the 93-m RZ generally lacked. hese were prime sources of food and cavity and eaf nest sites, and may have accounted for the igher squirrel numbers than in the wider RZ. he minimum width of RZ that will maintain quirrel populations appears to be about 55 m. ewer squirrels were observed in the 55 m RZ than n the other 2 wider RZ. RZ narrower than about 5-m do not support permanent resident populaions of squirrels. There was only light quirrel use in the medium RZ of 30 to 40 m idth. Only 1 squirrel was detected during the urvey, there were only 7 nests in 1,200 m of RZ, nd signs of squirrel feeding were sparse. No quirrels, 1 nest, and no signs of squirrel eeding were observed in narrow RZ.

Only 3 squirrels were seen from the planation edge points; all of these were in RZ, and o squirrels were detected in the 2-4 year-old lantations.

Both fox and gray squirrels were observed in he time-area counts in RZ. Mostly gray quirrels were detected in 2 of the wide areas nd fox squirrels were predominant in the other. ata collection, analysis, and writeup continue or the other animal groups.

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Table 1.--Number of squirrels observed during time-area counts and the number of leaf nests in riparian zones of various widths in eastern Texas

Riparian	Sept. 1984[1]		Sept. 1985[1]		
zone width	Total	No./h	Total	No./h	No. of nests[2]
Narrow (<25 m)	0	0	0	0	1
Medium (30-40 m)	1	0.1	0	0	7
Wide (>50 m)	12	1.5	12	1.0	55

[1] Two replications of each width sampled in 1984 (8 hours of observation per treatment), 3 replications in 1985 (12 hours per treatment).

[2] Found along 1,200 m of transect of each treatment, 400-m lengths in each replication in Feb. 1985.

Effects of Forest Practices on Relationships Between Riparian Area and Aquatic Ecosystems

Edwin Miller[1]

Abstract.--Riparian vegetation influences food energy, large organic debris loading, stream temperature, streambank and bed stability, terrestrial to aquatic buffering and streamflow of lower order forest streams. These functional areas are highly interrelated and affect determine aquatic productivity. Opportunities to manage riparian areas to meet timber utilization and aquatic productivity goals are promising. Research is needed in all areas to quantify the relationships and provide guidance for site-specific riparian management.

INTRODUCTION

The management of riparian areas for the protection of aquatic ecosystems has received attention in the forestry community during the past 10 years. Best management practices (BMP's) which include guidelines for streamside management have been developed and implemented either on a regulatory or voluntary basis in most states. Despite the development of riparian BMP's there is very little published information on how the manipulation of riparian vegetation affects aquatic ecosystems (USDA Forest Service and US Environmental Protection Agency 1978). Notable exceptions are in the areas of forest shade influence on stream temperature and riparian management effects on stream productivity in the northwest United States. The objective of this paper is to provide a brief outline of the relationship between riparian and stream communities. This will help foresters better understand the objectives underlying streamside management designs and identify some areas where an improved understanding of riparian influences on stream ecosystems would be helpful in guiding management strategies for riparian areas.

The quality of stream habitat for aquatic organisms is influenced strongly by riparian vegetation (Meehan et al. 1977). In a broad view there are six interrelated functions which the riparian area serves with respect to the aquatic environment: 1. Riparian vegetation provides a portion of the food energy for certain stream organisms; 2. large organic debris, which is an important component of some forest streams, is produced in the riparian area; 3. solar energy is regulated by the vegetation which shades the water surface; 4. the stability of the streambank and flood plain of smaller streams depends largely on riparian vegetation; 5. the streamside zone provides a buffer between the aquatic and terrestrial habitats, and; 6. streamflow is regulated to some extent by the riparian vegetation.

RIPARIAN VEGETATION AND THE STREAM ENVIRONMENT

Food Energy

In forest streams small enough to be completely covered by the forest canopy a large portion of the food base is supplied by the riparian vegetation. Leaves, needles, fruits, twigs, branches, boles, and insects from streamside vegetation may constitute 70-80 percent of the food energy supply to the aquatic system (Hynes 1970). This food is classified as allochthonous, meaning it originates from outside the aquatic ecosystem. With the exception of large woody material, the amounts, types, and timing of allochthonous inputs are seasonally regulated. A large percentage of this coarse organic material is used within the lower order streams by shredding and collecting organisms. Once this material is processed into smaller sizes, it is subsequently flushed and utilized by invertebrate organisms in higher order streams. The balance of food energy in the aquatic ecosystem is produced within the stream in the form of algae or aquatic vascular plants and is classified as autochthonous. This source of organic matter increases and may predominate in streams exposed to direct sunlight.

The utility of organic material to aquatic organisms in the stream depends on the type of material and the retention time in the stream (Meehan et al. 1977). For example, leaves are generally more easily used than wood, and hardwood leaves are generally more palatable and digestible than conifer needles. Easily decomposible materials supply a ready source of energy and nutrients while coarse or refractory materials provide a lower, yet less time-dependent supply of food. Retention time is the length of time material remains within a defined stream section and is therefore available for decomposition or consumption. Retention time is a function of stream morphology.

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Large Organic Debris

Tree boles, large branches, and root wads, classified as large organic debris (LOD), are supplied by riparian vegetation and become an integral part of many forest streams. This material strongly influences the structure (morphology) of small streams by forming pools (Swanson et al. 1976) and retaining or detaining the movement of sediment and gravel (Bilby 1981, Megahan 1982). LOD also increases the retention time of smaller organic material used as a food source (Bilby and Likens 1980), provides cover for fish (Bryant 1983, Sedel et al.1985), and is an important substrate for biological activity (Meehan et al. 1977). A change in stream channel structure and a reduction in habitat diversity can occur when LOD is removed from a section of stream (Bilby 1984b).

Stream Temperature

For stream organisms, temperature is one of the most important ecological factors because basic metabolic processes are temperature dependent (Ruttner 1963). The temperature of stream water also influences its oxygen holding capacity. Temperature can therefore limit the broad geographical distribution as well as the local (within-stream) occurrence of aquatic organisms including fish (Hynes 1970). Tolerances to temperature maximums, minimums, ranges and rates of change are radically different for the various aquatic organisms. The effect of a change in stream temperature regime on individual species can be insignificant or dramatic. Impacts include changes in growth, development, reproduction, and mobility. Because of the interdependence of various species in an ecosystem the disruption of the life cycles of one or a group of species may cause shifts in ecosystem productivity, species diversity, dominant species, or total numbers present. It should be stressed however that ecosystem changes which result from alterations in the stream temperature regime are not uniformily positive or negative but must be evaluated quantitatively and qualitatively in light of stream management objectives.

The primary source of heat for lower order forest streams is direct solar radiation on the water surface, whereas conduction, convection, and evaporation have little influence on stream water temperature (Brown 1969). Shade provided by riparian vegetation plays a key role in the regulation of solar energy inputs and therefore stream temperature. The effect of riparian shade removal on forest stream temperature has been shown in a number of studies across the U.S. (Brown and Krygier 1970, Levno and Rothacher 1967, Meehan 1970, Hewlett and Fortson 1982, and Swift and Messer 1971). Stream shade removal normally results in increased maximum temperatures, a greater diurnal range in temperature, increased rates of change, and, in some cases, reductions in daily minimum temperatures during winter (Swift and Messer 1971). In some situations stream temperatures decline after flowing through shaded reaches. Cooling of heated water is usually the result of cool water contributions from side streams and groundwater, and flow through coarse streambed gravel (Swift and Baker 1973, Bilby 1984a).

Streambank and Bed Stability

Geologic characteristics and processes are dominant factors affecting overall stream morphology. As stream order decreases, however, riparian vegetation is increasingly important in determining the morphology and stability of forest streams (Zimmerman et al. 1967). Vegetative protection of streambanks, and on smaller streams the streambeds, provides for the continued existence of discrete habitat types. Infrequent episodic flood events play a role in reshaping streambanks and beds. Although floods cause periods of instability, they provide for the critical restructuring of habitat and in some systems cause the addition of large organic debris which add to habitat diversity (Ward and Stanford 1983). The banks and beds of headwater forest streams are ready sources of sediment (Swanson and Fredricksen 1982). Riparian vegetation allows for the necessary natural bed and bank erosion processes, but effectively prevents accelerated erosion which would increase suspended loads and provide a continuing source of active bed load materials.

Suspended sediment loads rarely have a direct adverse effect on adult fishes (Wallen 1951) however, the ultimate results of increased suspended loads, although indirect, can be serious. Some examples include reductions in invertebrate abundances, decreased feeding success of sight feeding species, and dislocation and mortality of early life stages. Attributes of the stream such as stream temperature and nutrient levels can also be altered by increased suspended sediment loads. Increased bed loads and/or intrusion of fines into stream gravels can have a major influence on bottom dwelling species causing shifts in numbers, species, and diversity and also have a direct negative effect on the spawning success of salmonids as well as other fish species. There is an extremely wide range in the tolerance of various species to both suspended and bed load sediments precluding any further broad qualitative statements.

Terrestrial/aquatic Buffer

The riparian area acts as a buffer between the terrestrial and the aquatic ecosystems. The regulation and modification of inputs from the terrestrial zone, primarily nutrients and in some cases sediments, are among the buffering functions. Nutrient inputs due to leaf and woody matter addition are of major importance to the stream ecosystem but are considered a part of energy or food inputs discussed earlier. In this case we are considering mechanisms by which nutrient levels are regulated or altered as water passes over and through the flood plain, and situations where the riparian area can act as a filter to limit the inputs of upland sediments to the stream.

The relative importance of the streamside zone as a nutrient and sediment buffer to the aquatic system has not been well established, particularly for smaller forest streams. Wetlands have been studied for use as nutrient removal systems (Bender and Correll 1974, Tilton and Kadlec 1979) and Lowrance et al. (1984) found riparian forests to be an effective nutrient sink. References stating the importance of riparian zones as sediment filters are common (Meehan et al. 1977, van Groenewood 1977), yet reports documenting this function are difficult to find.

Forest systems are generally nutrient conservative and undisturbed forested soils are well protected from erosion. The opportunity or need for riparian areas to regulate nutrient and sediment inputs from the terrestrial portions of forested watersheds are therefore relatively minor. However, the opportunity for the riparian area to serve as a buffer for forest operations activities conducted on the watershed may be significant and is considered later.

Streamflow

Current speed (velocity) and discharge (rate) are important physical attributes of stream systems that have a major influence on the occurrence, distribution and spawning success of aquatic species (Hynes 1970). The relationship between riparian vegetation and the velocity of a stream depends basically on how the vegetation affects the roughness of the channel during low flows and the entire floodway during flood flows. Increased roughness decreases stream velocity whereas decreasing channel and flood plain roughness increases velocity (Gray and Wigham 1970).

The influence of riparian vegetation on stream discharge is not clear, however, increased annual stream discharge due to riparian clearing has been reported (Dunford and Fletcher 1947, Rowe 1963). Where fluctuating discharge or the seasonal drying out of streams eliminates selected or many aquatic species, increases in flow during critical periods may be advantageous, but the overall influence of streamside vegetation would have to be considered in such cases. It would appear that the influence varies from riparian stream systems in dryland or desert environs to those in the humid forest. Investigations have thoroughly demonstrated that forest harvest other than in riparian areas results in increased streamflow (Hewlett 1982) and those increases would seem to overshadow the effect of riparian clearing in humid areas.

MANAGEMENT OF THE RIPARIAN FOREST

Forest management options for the riparian area can range from no activity to complete vegetation removal. The no activity or leave strip option is practiced primarily on public lands where a conservative management perspective is coupled with a strong multiple use directive. On lands where an aggressive forest management program is underway, a balance between the costs and benefits of riparian management and stream habitat protection must be established. At the other extreme are those areas where the landowners goals or attitudes are incompatible with stream habitat protection, the maintenance of riparian values are not considered, and riparian vegetation is abused or eliminated. What are some of the generalized impacts on the six functions for a forest management option which includes the removal of selected timber from the riparian area with careful attention to stream habitat protection?

Food Energy

The basic relationship between food energy sources and the stream ecosystem is reasonably well understood and allows a qualitative assessment of timber harvest from the riparian zone. Removal of streamside vegetation would reduce the amounts of allochthonous material entering the stream might alter the quality and timing of allochthonous inputs, and would increase the amount of sunlight reaching the stream.

The extent and duration of reductions in allochthonous imputs following riparian timber harvest is highly site specific and would depend on factors such as the amount of canopy removed, rates of revegetation and crown expansion, allochthonous inputs from stands outside the riparian area, and upstream allochthonous contributions. For example, if the length of riparian harvest area was short, harvest levels low, and allochthonous contributions from upstream and/or adjacent areas large, total reductions in inputs to a stream segment might be small. Scenerios for large short-term reductions in allochthonous inputs could also be presented. Rapid revegetation or crown expansion following harvest could lead to overall increases in allochthonous inputs in a relatively short period of time following harvest.

Timber utilization and management goals will largely determine the species mix of the residual riparian stand while ecological factors will determine the species mix through the period of revegetation and crown development. The removal of individual trees in proportion to the original stand composition, for example, would initially result in little or no change in residual stand composition, whereas the removal of one or more selected species could change residual stand composition considerably. The impact of altering species on food quality and/or the seasonability of allochthonous inputs and ultimately stream productivity could be positive or negative and would depend on site specific factors.

Finally, increasing sunlight levels to forest streams can increase autochthonous production (Duncan and Brusven 1985a, 1985b) and subsequent increases in invertebrate production have been shown to increase fish production (Murphy and Hall 1981, Hawkins et al. 1983, Bisson and Sedell 1984). Results may vary for streams which are not nutrient or temperature limited, but these examples clearly illustrate that overall productivity is determined in part by the balance of terrestrial organic inputs and aquatic organic matter production. The overall impact of timber removals from the riparian zone on food energy cannot therefore be generally classified as negative and must be evaluated on a site specific basis.

Large Organic Debris

The importance of large organic debris (LOD) to stream systems is recognized, however, little information is available on rates of LOD inputs to streams from natural or disturbed riparian systems, how much LOD is needed to optimize fish or stream productivity or how to manage riparian areas to provide the sizes and types of LOD needed. This is certainly an area of research opportunity.

Webster and Swank (1985) hypothesized the following scenario for LOD inputs following logging. Depending on logging practices, there may be an initial increase in LOD from logging slash. Inputs could remain high for a short period as windthrow, breakage, and rotting residuals fall into stream channels. The second period would be dominated by successional vegetation development and a decrease in LOD inputs would occur. Later, as successional vegetation declines and shade tolerant or climax species prevail, an increase in LOD input would again occur. Finally during the long period of forest maturation, low inputs would prevail until natural mortality of the mature stand occurs.

With intermediate levels of timber removal or a selection management approach in the riparian forest, it would appear drastic shifts in LOD inputs could be avoided. Maintaining all age classes and a mix of species would be a key in such a plan. Where LOD is an important component of the stream channel, cleaning of stream channels following logging should be avoided if possible (Bilby 1984b) as a means to maintain LOD.

Stream Temperature

Research which has identified the relationship between riparian shade and stream temperature has also led to guidelines for shade management on streams where it has been determined water temperatures must be maintained for aquatic habitat protection. Vegetative strips which continue to shade small streams are the most effective means of stream temperature control (Brown 1972). Many factors determine the configuration of riparian shade necessary to control stream temperature. They include the size of the stream, its orientation, surrounding topography, and the species and density of shade vegetation. (Brown 1972) suggests that simply specifying the width of shade strips or the volume of riparian timber to be maintained are not effective ways to provide shade vegetation which meets timber utilization and stream temperature objectives. Determining canopy density and the portion of the canopy which provides stream shade during critical midday hours on individual stream segments is necessary. Individual trees and understory vegetation can then be identified and marked for protection in the process of planning the management of the riparian area. This requires the skill and judgment of the resource manager working on a site specific basis.

Streambank and Bed Stability

The roots and lower stems of both understory and overstory vegetation bind the alluvial sediments of the bed and bank together and act to hold large organic debris in place (Likens and Bilby 1982). Identification of this vegetation is straight forward as it is normally found growing on or directly adjacent to the streambank and within the bed of smaller streams. Removal or destruction of this vegetation reduces the strength of the bed and bank and allows accelerated erosion to occur especially during flood flows. Restabilization of streambanks and beds is normally a long term process in nature which emphasizes the need for uninterrupted streambank protection.

Providing a wide leave strip would normally assure complete bank and bed protection but this may not be necessary in many cases. As with stream temperature, identifying the critical vegetation for protection while providing for some level of timber removal allows for a more equitable balance between timber utilization and stream protection in the riparian zone.

Removal or damage of stream bank vegetation is not the only hazard forestry operations in the riparian area pose to streambank and bed stability. The indiscriminate felling of other riparian timber and adjacent upland timber, mechanized skidding or yarding operations which physically damage streambanks or streambank vegetation, frequent crossing of streams with machinery, and chemical supression of streambank vegetation are direct activities which can be especially destructive. Slash left in the riparian area can cause damage to streambanks and beds by accumulating during floods, damming and rechannelizing flow and initiating erosion processes. Properly managed, however, large slash can enhance stream habitat by enhancing LOD. Conducting management activities in the riparian area then requires site specific planning and training of operators in order to meet timber and stream management objectives.

Terristrial/aquatic Buffer

The natural function of the riparian area as a buffer between the undisturbed terrestrial and aquatic ecosystems may not be as critical to the aquatic ecosystem as food energy, solar energy regulation, or habitat stability. When the terrestrial area is under management, the importance of the riparian area as a buffer increases and logic suggests the more drastic the terrestrial activity the more important the buffer. Supporting a philosophy that the riparian area acts as a buffer or filter may tend to relieve managers from applying silvicultural practices in a way that adequately protects the terrestrial site as well as the stream. Soil erosion, for example, should be kept to a minimum on forested lands in order to maintain site productivity. Even if the riparian area were a perfect sediment filter, the foresters overall goals are not met by allowing soil erosion to occur. There are situations, however, when the buffering capacity of a riparian area or the separation of activities by providing untreated zones adjacent to sensitive sites is of benefit.

Riparian areas should be used as buffers to stream environments when forest chemicals - fertilizers, herbicides, and insecticides - are applied to the watershed. Factors which determine the hazard of any chemical are exposure and toxicity. Non-toxic chemicals pose little threat to organisms and toxic chemicals are no hazard if non-target organisms are not exposed. Exposure depends on the behavior of the chemical, where behavior is defined as: 1. the means of distribution of the chemical; and, 2. the movement and persistence of the chemical in each component of the ecosystem. In an excellent review of the impact of forest chemicals in streams, Norris and Moore (1970) indicate direct application to surface waters (improper distribution) is the major source of aerially applied chemicals in the aquatic environment. Excluding streams from treatment areas by providing untreated buffer strips is an extremely important first step to assure the proper distribution of forest chemicals.

The riparian area can also serve as a buffer from the mechanical activities involved in forest management operations. Exclusion of all mechanical activities in the riparian zone may not be necessary, but special precautions are required to prevent soil disturbance in the flood zone, damage to residual riparian vegetation, and the indiscriminate crossing of streams. Provision of a special streamside management zone emphasizes these special needs.

In some situations riparian areas can act as sediment filters for flow from upslope areas or for road drainage runoff. Miller et al. (1984) and Vowell (1984) reported providing a buffer area, with high infiltration capacity, between road drainage outfalls and adjacent streams, effectively reduced road sediment loads when flow discharges were low and flow was not channelized directly to the streams. The ability of the riparian area to filter sediments will depend largely on the volume and rate of flow entering the area, the sediment load, riparian ground cover, and infiltration conditions. Flow which is channelized when it enters the flood plain is generally channelized directly to the main stream and no opportunity exists to reduce the sediment load. When flow can be delivered to the flood plain at rates which allow dispersion and infiltration, opportunities for sediment filtration increase.

Flow Regulation

Riparian management ranging from no disturbance to moderate levels of overstory removal should have minor impacts on amounts of streamflow and rates of stream discharge in forested watersheds. Short-term increases in groundwater discharge to streams with moderate levels of timber removal might occur during summer low flow periods and potentially benefit aquatic organisms in streams which are flow limited. Increased groundwater discharge could also positively impact stream temperatures during stressful low flow periods.

CONCLUSION

The functions of the riparian area with respect to the stream environment can be classified into five areas - food, large organic debris, solar energy regulation, streambank and bed stability, terrestrial-aquatic buffer, and streamflow regulation. These functions are highly interrelated as they affect stream habitat and aquatic productivity. Riparian areas provide an important source of allochthonous food inputs and regulate autochthonous production by influencing light levels of smaller forest streams. Riparian vegetation is the source of large organic debris to the stream. Riparian shade is the key regulator of solar energy input and therefore the temperatures of small forest streams. Streamside vegetation is an important factor in maintaining streambank and bed stability and stabitizing large organic debris. Finally the riparian area is a terrestrial-aquatic buffer and influences streamflow characteristics, although these functions may be relatively minor in the undisturbed forested watershed. In general the functional influences of the riparian vegetation decreases as stream order increases.

Providing for totally undisturbed riparian areas is one approach to maintaining the food, temperature, and habitat stability requirements of streams, but does not address timber utilization goals, and does not necessarily lead to optimum levels of aquatic productivity. Research results indicate opportunities exist for timber utilization in the riparian area but at lower intensity and using methods which recognize and meet stream temperature, food, and other stream habitat requirements. In some cases timber management may be designed and conducted to enhance stream productivity. The relationship between riparian vegetation and stream productivity is highly dependent on site specific factors, and likewise, riparian management must be designed on a site specific basis to adequate address timber utilization and stream productivity goals.

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Assessment of Wildlife Damage on Southern Forests

James E. Miller

Abstract. This paper summarizes results from a mail questionnaire sent to forest managers and natural resources agencies in 16 southern States to determine the extent of damage caused by principal wildlife species to southern forests. Annual wildlife damage to southern forest resources was estimated by respondents to this questionnaire to be $11,182,641 with another $1,643,218 annually being expended in attempts to prevent or control damage on 28,380,182 hectares (70,950,455 acres) of forest lands. Conclusions and implications drawn from this and other survey studies indicate that many natural resources managers are reluctant or unwilling to provide monetary estimates of damage caused by vertebrate animals. Reasons for this reluctance are discussed in the paper, however, the lack of practical and effective assessment methodologies or models for determining damage costs is the most significant.

INTRODUCTION

Vertebrate wildlife species have long been considered one of the manageable resources produced on forest lands in the South and many of these have high social and economic values attributed to them by the public, and by the variety of landowners, managers and users. Some wildlife species may at times, however, cause significant economic damage to valued resources and related properties as well as problems and frustration for the landowner, manager and community.

This study was conducted in an attempt to provide some estimates of the magnitude of damage caused by vertebrate wildlife species to southern forests, to delineate some concerns and needs related to the issue, and to encourage stronger consideration of the issue in future natural resources management planning efforts.

The prevention and control of wildlife damage on forest lands is an old and complex problem that rarely is easily accomplished and is commonly misunderstood. It should be a part of any natural resource manager's land management objectives, even though it may be controversial. Wildlife damage prevention and control on southern forest lands is as essential to any comprehensive forest management program as the prevention and control of wildfire, diseases and insect damage. Unfortunately, in the past many natural resources managers, including some wildlife biologists, have perceived wildlife damage prevention and control as detrimental to other management objectives or at best, as an unplanned for, adjunct necessity when damage or losses become significant.

In recent years, however, both natural resources agencies and organizations and most wildlife professionals have come to realize that wildlife damage prevention and control is a vital part of natural resources management. A comprehensive natural resources management plan with objectives for the effective prevention and contro of wildlife damage will require a commitment of resources to research and management, a knowledge of current regulations, the capability to assess the cost/benefits of damage/risk and the cost effectiveness of prevention and control methods. As an example, consider the following quote from the (International Association of Fish and Wildlif Agencies 1981), position statement on Animal Damag Control. "A well balanced wildlife management program includes research, the acquisition of land the development of habitat, the careful regulation of hunting or harvest, the protection of certain species, the enforcement of laws--and the control of animal depredations. Though necessary, this is among the least popular and most controversial of the wildlife management functions. It is, nevertheless, one of the activities which a responsible agency must undertake."

Further evidence of the assigned importance o this management consideration in recent years can

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ound in Department Policy as well as essional society position statements. Two good ples are the U.S. Department of Agriculture, rtmental Regulation 9500-4 Fish and Wildlife cy (USDA 1983) and the position statement and cy of The Wildlife Society (TWS 1985) adopted arch 19, 1985.

To incorporate an animal damage control ram into a comprehensive natural resources gement program, questions for consideration (1) If wildlife damage prevention and control management issue -- do we address and plan for n our natural resources management objectives? Do we feel confident in our capabilities to ss accurately the impacts of wildlife damage ed by some species and/or wildlife benefits lting from species-selective, damage abatement? Do we support sufficient research and nology development to establish and maintain cacious prevention and control measures? (4) Do ave the commitment, training and expertise to ement environmentally safe and cost-effective ention and control measures to reduce damage/ es to an acceptable level?

Some related facts that we can be confident however, include: (1) Wildlife damage has ys been a vital element in the protection of n interests; (2) As human populations continue ncrease and their needs expand, wildlife ies will have even greater frequency of direct ndirect contact and conflicts with humans and r interests in both rural and urban unities; (3) The prevention and control of llife damage is complex and can rarely be solved t one universal, simple technique; (4) The olem will rarely solve itself, if ignored; (5) gnored, it can force the landowner, manager or unity to implement control practices that erbate the problem, are environmentally rdous and/or eliminate remaining habitat for vertebrate wildlife; and (6) Wildlife damage ention and control measures will always be roversial even though these practices may be ntial for effective natural resources gement.

STUDY AREA

Federal and State land management agencies and of the large forest industries in the 16 hern States that make up the Southeastern ciation of Fish and Wildlife Agencies were sent -administered, mail-back questionnaires. The ective States where appropriate personnel were acted included: Alabama, Arkansas, Florida, gia, Kentucky, Louisiana, Maryland, issippi, Missouri, North Carolina, Oklahoma, h Carolina, Tennessee, Texas, Virginia and West inia. Federal and State agencies and the gories of personnel who responded were as ows: USDI-Fish and Wildlife Service, - onal Wildlife Refuge Managers; all Region 8 - Forest Service Supervisors; USDI National Service - Supervisors; State Cooperative nsion Service - Wildlife Specialists; State and Wildlife Agency - Directors or staff; Forestry Commission - Directors or staff; USDA, Animal Plant Health Inspection Service - Animal Damage Control, - State Directors; and Department of Defense - Land Managers. The non-governmental organizations surveyed included professionals from 15 major forest industry ownerships within the 16 States. No attempt was made to survey private non-industrial forest landowners even though they are the principal forest landowners in the South and often suffer the most animal damage losses.

METHODS

The questionnaire was developed by the author with review by Federal and State agency professionals. The purpose and objectives of the questionnaire were delineated on an accompanying cover letter. It was clearly stated on the cover letter that respondents should ... "please answer the questions with the best estimate available from your own personal knowledge or that provided by knowledgeable personnel from your agency or organization." Information compiled from these questionnaires are estimates only of the extent and impact of vertebrate animal damage to some southern forest resources.

Total response to the questionnaire, with explanatory cover letter and self-addressed, postage-paid return envelope was 67%. The exemplary cooperation and support of administrators within the appropriate agencies and organizations is sincerely appreciated. Their support and assistance helped ensure the excellent, short turn-around response to this questionnaire.

The questionnaire consisted of 10 questions regarding wildlife damage and the prevention and control of this damage to southern forest resources. Beginning with the first question, the respondent was prompted to list the acreage of lands by category/ownership where they had knowledge of the extent and severity of damage by vertebrate species to forest resources. The total acres owned/managed or reported by respondents was approximately 28,379,823 hectares (70,125,581 acres) of the total 91,567,705 hectares (226,260,700 acres), or about 31 percent of the commercial forest lands in these 16 southern States (1982 U.S. Forest Service).

Species and groups of vertebrate animals known to cause damage to forest resources in the South were delineated and space for "others" was provided with the request to "specify" if the space adjacent to "others" was checked. For the remaining questions, the respondent was given the opportunity to exercise subjectivity in determining their answers. A figure of greater than $400 damage per year was used to differentiate annual significant damage to forest resources from non-significant. The figure of $400 was selected based on a study of "Landowner Tolerance of Beavers" (Purdy et.al. 1985), which indicated that landowners were tolerant of damage up to the point where it exceeded $400 per year.

The species list of animals known to cause damage to southern forest resources were as follows: white-tailed deer (Odocoileus virginianus); beaver (Castor canadenis); rodents (mice, rats, squirrels, etc.); bear (Ursus americanus); wild or feral hogs (Sus scrofa); rabbits (Sylvilagus spp.); birds (specify); others (specify).

Obviously, evaluation and assessments of damage caused by wildlife are difficult to determine in monetary terms, and few research efforts have been targeted toward obtaining scientific assessments. This is one of the reasons that an effort was made to obtain best estimates of vertebrate animal damage to southern forest resources with this questionnaire. It further points to the need for additional consideration by researchers to develop better models and/or systems for practical damage assessment that can be used by managers.

RESULTS

A total of 234 questionnaires were forwarded to the various Federal and State land managing agencies and industrial forest land managers. Ninety-eight of the 157 respondents (62%) indicated significant damage (e.g., more than $400) caused by one or more vertebrate species during the past 12 months on portions of 26,880,776 hectares (67,201,940 acres). Thus, 59 of the 157 provided no monetary estimate of significant damage to forest resources caused by vertebrate species on 1,499,406 hectares (3,748,515 acres) (Table 1). The total acreage owned, managed or reported by respondents was 28,380,182 hectares (70,950,455 acres), or about 31% of the commercial forest lands in these 16 southern States (U.S. Forest Service 1982).

As reported in numerous other studies (e.g., Woodward 1985), many respondents were neither confident in assessing damage caused by vertebrate species nor were willing to provide economic estimates of such losses even if willing to report that damage was extensive. Thus, some respondents reported little or no damage whereas previous studies in their State have documented millions in damages. It was also evident that some respondents may not have correctly interpreted the question. Where damage estimates were less than the estimated control costs, either the damage was apparently underestimated, the control implemented reduced the damage significantly, or damage was being caused to roads or other property not interpreted as impacting on forest resources. Other conclusions are that damage prevention or control can be so effective that subsequent damage is insignificant or it is not cost-effective as reported for some species. Another possibility is that control is being implemented out of frustration or to prevent expected damage. Frustration and anticipated damage are legitimate reasons to effect prevention or control measures, but difficult to estimate in monetary figures, e.g., periodically having to clean out culverts, or significant damage on adjacent properties.

Respondents estimated annual damage to southern forest resources from all vertebrate wildlife species at $11,182,643. They further estimated another $1,645,218 expended in preventi or control efforts over the past 12 months (Table 2).

Respondents to this questionnaire reported th beaver as causing the most significant damage, estimated at $10,162,263 annually to southern forest resources. Other species of wildlife reported by respondents as causing significant damage in descending order of annual dollar estimates are: white-tailed deer; birds; "other" wildlife; rodents; rabbits; wild or feral hogs; a bear (Table 2).

By far, the species of greatest interest and significance in recent years to southern forest managers has been the beaver, as was confirmed in this study. Review of the Southern Journal of Applied Forestry paper titled "Beaver Damage to Non-Impounded Timber in Mississippi" (Bullock and Arner 1985) reported "Computations made with the lowest (stumpage) value of nearly $87.00/acre estimate the total value of non-impounded timber damage by beaver to be nearly $215 million, occurring over a period of at least 10 years." Other surveys, research and papers reported in th literature substantiate the significance of beave damage to forests in the South. Earlier studies (Arner and Dubose 1980) projected annual timber damage caused by beaver to be $17 million in Mississippi and (Godbee and Price 1975) estimated annual total timber losses at $45 million in Georgia.

Significant damage caused in the South by beaver to timber through flooding, girdling, cutting, and other damage including roads flooded and culverts stopped up has been reported since the mid-sixties, and, in fact, some forest industries had contracts for control of beaver even earlier. The status of beaver today across most of the South is that viable populations exist in almost every suitable habitat.

In terms of estimated annual expenditures fo prevention and control efforts, the total for eac species in order of magnitude were as follows: beaver; followed by wild or feral hogs; white-tailed deer; rodents; rabbits; "others"; birds; and bear (Table 2). The estimated cost of prevention or control of wild or feral hogs was over 3 times greater than the estimated damage losses and more than double for bear. For all other species, the estimated costs of control were exceeded substantially by the estimated damage losses, which is more commonly the situation with efforts to prevent or reduce significant damage.

As previously reported, 59 of the 157 respondents either had no significant damage from vertebrate wild species or were not comfortable i estimating the damage in monetary terms, even whe the cover letter clearly emphasized that only the best estimates were being requested. Some of the respondents who would not make a monetary judgmen that damage exceeded $400 per year would point ou that although damage caused by one or more specie was extensive, they would not attempt an estimate In response to other questions, some reported

age caused by wildlife as being extensive but
ed that they were not comfortable making a
etary estimate of the damage. Others questioned
ther the damage estimate was only for trees
led or if it included yearly production lost
n flooded lands. Still others simply admitted
t they were unable or unwilling to calculate the
s or to determine the number of acres where
age was occurring.

Others indicated that because of their
ncy's or their own management philosophy, they
not consider depredation or damage caused by
of the species as a problem; the intrinsic or
er values these species offered thus outweighed
sideration of losses foregone to forest
urces. Two respondents reported negligible
ber damage but indicated significant damage to
ds, depredation to other natural resources, or
lation on preferred wildlife species.

Respondents indicated that they would more
ily estimate species population trends than
empt to estimate monetary damage. Although only
f 157 respondents estimated significant
etary damage to forest resources over the past
onths, 107 respondents checked one or more
d estimate(s) for species causing damage to
est resources.

Less than one-half of the respondents were
e of the recent Handbook on Prevention and
rol of Wildlife Damage (Timm 1984) and fewer
participated in a regional or national workshop
n-service training on animal damage control
in the last five years. Of the 149 respondents
his set of questions: 46 either had a copy of
Handbook or access to one; 28 had seen or heard
he Handbook but did not own or have access to
77 were not aware that such a Handbook was
lable; and only 17 of the 149 respondents had
icipated in a regional or national workshop,
erence or in-service training on animal damage
rol within the last five years. These findings
cate the level of interest in, and need for,
eased access to quality information about
al damage prevention and control and greater
icipation in workshops and other in-service
ning in this subject by forest resource
gers. Most of the 77 respondents who indicated
did not know that the Handbook was available
cated an interest in finding out how to obtain
py.

CONCLUSIONS

Although the scope of the questions asked, the
of potential respondents surveyed, and the
dity of the estimates in this study were
ted, some general conclusions are implied.
rently many professional land managers are not
ortable in answering detailed and complex
tions requesting monetary estimates of animal
ge to forest resources. There could be a
ety of reasons for the reluctance to respond to
questions, however, I believe it is safe to
me that the most common reasons are: (1) Most
s would like to have hard data (which is rarely
tical); (2) Viable damage assessment methodologies or models are not available for practical use; (3) Few of us have really been required to evaluate animal damage losses/costs or the cost-effectiveness of prevention and control practices; and (4) Even though managers may have reasonably accurate estimates of the monetary value of a forest stand, they are still reluctant to estimate the monetary loss of wildlife damage caused to that stand, unless specificially required to do so.

Some other conclusions drawn by the author during the course of this study are as follows:

1. Without question, beaver is the vertebrate animal causing the most damage to southern forest resources at the present time. From respondent's answers regarding population trends, beaver is also the species most often reported to have increased over the past five years. White-tailed deer was another species named by respondents as increasing significantly, and in the "other" category, several respondents listed the increasing coyote (Canis latrans) population as a concern because of predation on preferred wildlife populations.

2. When examining comments to the questionnaire, it was evident that wildlife damage losses and frustrations caused to a landowner or manager cannot and should not be evaluated in terms of averages, either regionwide or statewide. Each case must be evaluated on-site as to the magnitude of damage and cost-effectiveness of prevention or control.

3. There is a significant need for development of practical and effective vertebrate animal damage-loss assessment techniques and methodologies and for the determination of the cost-effectiveness of prevention and control measures.

4. Although several institutions are expanding their curriculum to offer courses in animal damage control for natural resources managers, there remains a significant need for in-service training for on-the-job professionals.

It is evident from previous studies reported in the literature that the prevention and control of vertebrate animal damage losses is an essential element for people's well-being, whether to prevent losses to agricultural crops, livestock, forests, desired wildlife habitats, other properties, or to prevent disease epidemics and other health hazards. It is time that natural resources managers cooperatively take the initiative to encourage and support necessary research, development, operational, technical assistance and educational programs in wildlife damage prevention and control.

Table 1.--Responses to questionnaires concerning vertebrate animal damage in southern forests

Affiliation	Total Respondents	Response (%)	Reporting 1/ Significant Damage		Reporting No Damage	
			Number	Hectares	Number	Hectares
National Wildlife Refuges	45	63	22	196,214	23	68,957
U.S. Forest Service	15	94	12	3,452,551	3	285,330
Military Lands	37	62	21	367,456	16	280,235
National Park Service	6	75	3	57,063	3	645,901
State Fish and Wildlife Agencies	11	69	6	217,330	5	No Esti
State Forestry Commissions	11	69	6	9,044,266	5	214,936
State Extension Service Specialists	9	56	8	87,998	1	No Esti
Animal Plant Health Inspection Service Animal Damage Control State Directors	10	71	7	7,527,019	3	4,047
Forest Industry	13	87	13	5,930,879	0	0
TOTAL	157	67%	98	26,880,776	59	1,499,40

1/Significant damage was that exceeding $400; no damage means less than $400

Table 2.--Monetary estimates of damage and control efforts for wildlife in southern forests

Species	Damage ($)	Prevention or Control Efforts Implemented	Control Effort ($)
White-tailed Deer	420,800	Yes	69,000
Beaver	10,162,263	Yes	1,368,683
Bear 1/	1,100	Yes	2,250
Wild or Feral Hogs 1/	40,100	Yes	126,700
Rodents 2/	121,100	Yes	31,450
Rabbits	91,500	Yes	21,400
Birds 3/	222,000	Yes	7,900
Others 4/	123,780	Yes	17,835
TOTAL	$11,182,643		$1,645,218

1/ Estimated costs of control efforts exceeded total damage losses estimated. Although several responden knew the expense of control efforts for these species, some were reluctant to estimate the monetary damag incurred.

2/ Other rodents specified included voles and pocket gophers.

3/ Birds specified included woodpeckers, blackbirds, goldfinches and mourning doves.

4/ "Others" specified included cattle, feral dogs, javelina, and coyotes.

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The Influence of Silvicultural Practices on Fisheries Management: Effects and Mitigation Measures

Monte E. Seehorn

Abstract.--Silvicultural operations often create severe impacts upon aquatic communities. This paper addresses basic requirements of several species of fish and points out some of the impacts caused by silvicultural activities. Methods or techniques for reducing level of impact are presented.

INTRODUCTION

Stream fishery management, for descriptive purposes, can be separated into population and habitat management programs. Population management refers to the manipulation of populations through application of harvest laws and regulations. Habitat management, although indirectly affecting population structure, refers to actions that maintain or modify the overall stream environment. Habitat management consists of protection and enhancement programs. Protection is often considered as maintaining the *status quo*, while enhancement programs are designed to improve habitat conditions. The difference is not always clearcut, because, in some cases, protection of existing habitat ensures gradual improvement or enhancement over the long term. A major distinction in objectives is that protective programs consist of those measures taken to safeguard fishery resources from concurrent land use or forest management programs. Direct enhancement activity, in contrast, may be performed independently of other program activities. This paper deals primarily with the protection of fish habitat from impacts resulting from silvicultural activities. Various strategies for reducing or mitigating such impacts are presented.

HABITAT REQUIREMENTS OF FISH

Southeastern fisheries include habitats ranging from subarctic to subtropical conditions. Appalachian brook trout (*Salvelinus fontinalis*) found at elevations exceeding 5,000 feet contend with climatological features equivalent to those in southern Canada. Bowfin (*Amia calva*) thrive in subtropical conditions, at the other end of the spectrum. Stream gradients range from precipitous waterfalls in the mountains to barely flowing Coastal Plain streams with gradients of a centimeter per kilometer. Maximum stream temperatures range from less than 15 °C to more than 30 °C. With the extreme diversity of habitat conditions and resultant diversity of organisms, formulating guidelines suitable for protection of all species is a difficult and complex task.

Thermal Requirements

Thermal criteria for representative species or species groups are shown in table 1. These criteria are very general and based upon various studies (Cincotta and Stauffer 1984, Lee and Rinne 1980, Moyer and Raney 1969, McCormick and Wegner 1981, Wrenn 1980) and my field observations. The limits shown are not absolute because factors such as water quality, age of fish, acclimation time, and duration of maximum temperatures affect tolerance. Other associated species may have broader or narrower limits.

All fish seek habitats that meet their own thermal preferences even if tolerance limits are relatively broad. Removal of shade and the resultant increase in stream temperature can cause fish to migrate. Greene (1950) cited a study in the Great Smoky Mountain National Park

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ble 1.--Thermal requirements of representative species and groups of fishes

	Degrees Centigrade	
ecies or group	Maximum	Optimum
ook trout (*Salvelinus fontinalis*)	21-24	13-15
own trout (*Salmo trutta*)	21-26	15-17
inbow trout (*Salmo gairdneri*)	21-26	15-17
allmouth bass (*Micropterus dolomieui*)	30-33	24-29
dbreast (*Lepomis auritus*)	30-33+	24-29
dhorse (*Moxostoma spp.*)	30-33	24-30
deye bass (*Micropterus coosae*)	30-33	26-29
otted bass (*Micropterus punctulatus*)	31-33+	26-30
rgemouth bass (*Micropterus salmoides*)	31-33+	26-30
uegill (*Lepomis machrochirus*)	31-33+	26-30
lden Shiner (*Notemigonus chrysoleucas*)	34-36+	16-23

which upstream migration of brook trout was multaneous with removal of shade. He noted other study in Pennsylvania where brook trout igrated from a section of stream because of vere overbrowsing of streamside willows by er.

In some southeastern streams, brown and inbow trout reproduce and sustain themselves water temperatures occasionally exceeding 24 . The key to survival under such maxima is e diurnal temperature fluctuation in which ghttime temperatures drop to 20 °C or ss. A study (unpublished data) of a small ream in northeast Georgia illustrated aphically the importance of this uctuation. Small (approximately 2 hectares) poundments were constructed on four headwater reams containing rainbow trout. The maximum mperature recorded above either impoundment the warmest 2-week period was 19.6 °C with nimums several degrees less, while below the poundments maximum temperatures ranged from to 23 °C. In a normal situation, these wnstream maximums would stress, but not kely, eliminate trout. In this case, trout re eliminated in the sections immediately low the outlets becase of the high *minimum* mperature. The impoundments, acting as a at sink, eliminated the normal fluctuation d held temperatures to 21 °C or above for e entire 2-week period.

Small changes in stream temperatures also ve subtle to dramatic impacts upon other mponents of the aquatic community. Wojtalik d Waters (1970) found that as the temperature creased there was a serious depletion of the yfly *Baetis vagans*.

awning Requirements

Stream salmonids require a clean gravel bstrate in which to deposit eggs. A redd veral inches in depth is excavated in small medium size gravel. Eggs are then posited, fertilized and covered with gravel splaced from redds constructed immediately stream. For optimum survival the gravel terstices must remain free of fine sediment in order to allow unrestricted circulation of water to the eggs and escapement avenues for fry upon hatching. An increase in sediment less than 0.85 mm is especially critical.McNeil and Ahnell (1964) showed a sharp increase in trout fry mortality when these fine sediments exceeded 20 percent of the total substrate. Irving and Bjornn (1984) reinforced these conclusions, indicating significant reduction in survival of three species of salmonids with an increase in sediments less than 0.85 mm in diameter. In their study, particles 0.85 to 9.5 mm had relatively little effect upon survival. Witzel and MacCrimmon (1983), in a different approach, showed brook-brown trout survival of 0 to 20 percent from hatching to emergence in unigranular gravel 6.2 mm or less, and in multitextured gravel with 60 percent or more sand. Survival was 60-90 percent in 9.2 mm gravel and gravels with 20 percent or less sand.

Spawning habits of riverine darters (*Percidae*) vary widely by species. Some scatter their eggs above the substrate, some bury their eggs, some place them between angled rocks and the substrate, and some cluster them on the underside of stones. Those species that bury their eggs and attach them to the underside of stones require relatively sediment free substrate for the same reasons necessary for salmonid survival.

Stream centrarchids such as bass and other sunfish also require firm substrate for spawning. Beds are usually fanned out in gravel where available, although sand is utilized *in lieu* of coarser materials. The eggs are then deposited, fertilized, and guarded by the male until the fry hatch. Although not as critical to survival of eggs and fry as in the salmonids and some of the darters, heavy deposits of fine sediments blanketing the beds likely reduce survival. For spawning and other reasons, species such as smallmouth bass (Rankin 1986, Paragamian 1981) and redeye bass occur only in streams or reaches of streams with predominately gravel and larger rock substrate. Even spotted bass, which proliferate in a variety of habitats including sandy coastal plain streams, seem to prefer such habitat if available.

Redhorse suckers, madtoms (Noturus spp.) and other species of fish also use gravel and rubble shoals or riffles for spawning purposes and are likely to be adversely affected by increased sediment loads.

Food and Cover Requirements

Many species of juvenile fish, including trout (McCrimmon 1954), rely heavily upon clean gravel riffles for cover during early life stages, while some darters and madtoms spend their entire lifespan in this habitat. In addition to the fish cover provided, this type substrate is an ideal medium for invertebrate production.

As winter temperature drops into the 5 to 10 °C range, metabolic rates of fish decrease, reducing food requirements and lowering swimming ability. Under such conditions, cover or shelter becomes especially critical (Mason 1976). At temperatures less than 4 to 6 °C, juvenile salmonids enter crevices in the substrate to survive icing and concurrent harsh winter conditions (Bjornn 1971). Larger fish, including stream bass and other sunfish, react in a similar manner by moving into deeper pools containing shelter in the form of large cobble, boulders, and logs. Soil erosion and resultant stream sedimentation that fill the substrate interstices destroy this critical component of the habitat.

The higher turbidity accompanying erosion also has a negative effect upon sight feeders such as bass, (Buck, 1956) bluegill (Gardner 1981), and trout (Sigler and others 1984). Juveniles are most seriously affected, but growth rates are reduced even in adult fish. Gradall (1982), in a laboratory experiment pointed out the strong possibility that increased turbidity likely favored production of creek chubs over brook trout.

Numerous studies point out the value of woody debris as a component of quality fish habitat (Sedell and Swanson 1982, Angermeir and Karr 1984, Bryant 1985, Coulston and Maughan 1983). In addition to the cover provided, snags and other woody debris are also important in relation to invertebrate food production. Benke and others (1985) illustrated this in a study of the Satilla River in Georgia. He stated that instream snags supported 60 percent of the total invertebrate biomass, and that the major fish species obtained at least 60 percent of their prey biomass from these snags.

POTENTIAL SILVICULTURAL IMPACTS

Removal of Shade

Shade removal can severely impact fish populations by increasing stream temperature. Numerous studies have documented increases of 4 to 10 °C after shade removal (Brown and Krygier 1970, Burton and Likens 1973, Swift and Baker, 1973, Swift and Messer, 1971). Increases of such magnitude would have severe impacts upon all aquatic organisms. Swift (1982) observed temperature increases at least 5 years after shade removal, although maximums were reduced each succeeding year because of the regrowth of vegetation. Slash burning can amplify stream temperature increase after shade removal. Levno and Rothacher (1969) found that the maximum temperature increased by as much as 7.7 °C after broadcast burning of logging slash. A critical factor in this study was that maximums were exceeded by 30 percent (889 hours) of the June, July, and August monitoring period.

Erosion and Sedimentation

Erosion and resultant stream sedimentation is the most common and difficult problem encountered in silvicultural operations. The effects are subtle in many cases, and are hard to detect by normal sampling techniques. Sediment can originate from several phases of the silvicultural operations, but the transportation system needed to implement the operations is by far the major source. As much as 90 percent of the sediment in streams can be traced to the roads, log landings and other components of the transportation system (Packer and Christenson). Cederholm and others (1981) pointed out that where roads exceed 3 percent of a basin area, fines are consistently higher than normal and, where as much as 4 percent of the drainage is in gravel-surfaced roads, sediment production is increased by a factor of four. The same study showed fish survival to emergence decreased by 2 to 4 percent for each 1 percent increase in fines less than 0.85 mm.

McMinn (1984) in a North Georgia study measured 37 percent soil exposed and 25 percent dislocated in a tractor operation removing 27.6 cords per acre from upper piedmont slopes ranging from 18 to 22 percent. In a concurrent sale using a Bitteroot skyline miniyarder to remove approximately 14 cords per acre from mountain slopes ranging from 24 to 42 percent, only 1 percent of the soil was exposed and none was dislocated. Although volumes of timber removed were not equal, the disturbance in proportion to cut was much greater on the tractor operation. Klock (1975), in summarizing the results of seven studies, showed less than 5 percent deep soil disturbance on sale areas when utilizing balloon, helicopter and some skyline cable systems. Soil disturbance on high lead cable and tractor operations ranged from 15 to 20 percent and 20 to 35 percent, respectively, because of the more extensive transportation systems required.

Kochenderfer and Helvey (1984), after measuring soil losses from 11 road sections in the central Appalachians, reported an average of 16.3 metric tons of soil per hectare lost annually from ungraveled sections, and only 1.98 metric tons per hectare lost on sections surfaced with clean 3-inch stone. Swift (1984) found soil losses of approximately .018 metric tons per ha from a well graveled (15 cm deep) roadbed per 2.54 cm of rain, compared to .308 metric tons for grassed roads, and .499 metric tons for bare soil roadbeds in the southern Appalachians. He pointed out that in the third year a thin layer (5 cm) of rock was little or no better than bare soil.

Heidsdorf (1984) presented the potential advantage of using skidders with wide, high flotation tires instead of conventional tires with front chains on swampy ground. Productivity was increased and previously inaccessible stands became operable with a substantial reduction in ground disturbance and compaction.

Biller (1984), in a study in the mountains of Virginia, compared road requirements for an FMC FT-180C[1/] high-speed, low-pressure skidder versus a rubber-tired skidder. The FMC required 42 percent fewer skidroads than the rubber-tired skidder while operating on grades ranging from 10 to 44 percent. The reduction in roading makes possible a significant decrease in overall disturbance. This type equipment, although having some advantages over rubber-tired skidders, can also create erosion problems if not used properly. Sidle and Drlica (1981) measured bulk densities of soils utilizing both uphill and downhill skidding with the FMC. At the 7.5 cm depth, nine passes increased bulk density for downhill and uphill yarding by 25 percent and 45 percent, respectively. Eighteen passes increased bulk density 25 percent at 22.5 cm. With only three or four passes however, bulk densities increased only 10 percent throughout the first 30 cm of mineral soil.

Mechanical site preparation has been documented as one of the more serious contributors of sediment in silvicultural operations. Dissmeyer and Stump (1978) presented the following data (table 2) on sediment produced by some of the techniques and equipment used in these operations. Bulldozing in mountain areas was by far the most serious source of sediment. The methods used in bulldozing were similar to shearing and windrowing except that a straight dozer blade was used instead of a K/G or V cutter blade.

Douglass and Goodwin (1980) found that soil loss from mechanical site preparation varied with percent cover and runoff on 16 small watersheds in the North Carolina Piedmont. Average summer ground cover accounted for 75 percent of the variation. They suggested use of site preparation techniques that leave at least 50 percent ground cover.

Douglass and Van Lear (1983) evaluated the effects of prescribed burning on stream water quality in the South Carolina Piedmont. They found no significant change in water quality. With proper precautions, prescribed burning should be feasible even on fairly steep terrain. If burns are hot enough to destroy the entire surface litter, however, serious erosion may occur.

Effect Upon Streamflow

Removal of the canopy on an entire watershed significantly changes streamflow patterns. Low summer flows may be doubled with less than 10-percent increase in peak flows in Appalachian Forests (Hewlett and Helvey 1970). Although clearcutting 50 ha in a 5,000 ha watershed would have no measurable effect upon discharge, cutting 50 ha in a 250-500 ha watershed may have a significant effect. Douglass (1979) calculated the potential gain in water yield between 20 year and 300 year timber rotations on 2,560 ha to be over 4.18 million liters per day. Clearcutting drainages as small as 8 ha in the Appalachians can change streamflow from ephemeral or intermittent to perennial until regrowth occurs. Douglass and Swank (1975) presented an equation for predicting annual increase in flow based upon percent basal area cut. They also pointed out that conversion from hardwood to pine decreases streamflow by increasing interception and evaporation rates due to the greater surface area of the pine needles compared to hardwood leaves. This decrease is most evident in winter months although flow rates are decreased throughout the year.

Nutrient Export

Studies at the Coweeta Hydrologic Laboratory in North Carolina (Douglass and Swank 1972, 1975) and at the Fernow Experimental Forest in West Virginia (Aubertin and Patric 1974) indicate comparatively small nutrient losses from clearcut areas. The Fernow study indicated a net loss of only 3.4 and 2.8 kg per ha more nitrate-nitrogen and calcium from a cut area than a control area in the first 34 months. These losses decline as regrowth occurs. Swank and Caskey (1982) showed a twentyfold increase in export of nitrate-nitrogen from a clearcut hardwood forest in a second order drainage, although total loss was less than 1 pound per acre annually due to naturally low nitrogen levels and instream depletion.

[1/] The use of trade or firm names is for reader information and does not imply endorsement by the U.S. Department of Agriculture of any product or service.

Disturbance	Period (yrs.)	Coastal Plain	Piedmont	Mountains
Natural	-	.00	.00	.00
Grazing	-	.16	.95	
Logging (excl. rds.)	3	.45	.48	1.70
Prescribed burn	2	.15	.14	.16
Chopping	3	.21	.22	
Chop and burn	3	.36	.38	
Shear/windrow	4	.57	1.80	4.00
Discing	4	2.16	4.10	
Bedding	4	.58	-	
Bulldozing	4	.78	1.90	13.70

Loss of Organic Materials to the Stream Systems

Silvicultural operations removing streambank vegetation have other impacts upon fish populations in addition to that of temperature change. Trees falling into streams are the source of large woody debris necessary for desirable fish populations. Many streams lack such debris, due to the removal of all large streamside trees in the logging operations of the early 1900's, and overzealous removal of existing instream debris through various development projects. Existing second-growth stands have not matured enough to be an adequate source of such material. If we continue to remove all large trees from the streambanks, these undesirable conditions will be extended far into the future.

Introduction of Toxicants

Pesticides can be introduced into stream systems through both ground and aerial spray operations. Some, such as 2,4-D derivatives, are relatively harmless, while others such as paraquat are extremely toxic to aquatic organisms.

Disturbing soils in certain geological formations may introduce toxic materials into the aquatic system. Fisheries were destroyed in two Appalachian streams by road construction that exposed Anakeesta/Wilhite formations. Iron pyrite, a component of these formations, when exposed chemically reacts with air and water to produce sulfuric acid. In at least two locations on one road the rock was crushed and used as fill material. Acid leaching from these road fills reduced stream pH drastically, resulting in further chemical reactions that released aluminum, manganese, and other toxic materials into solution.

Diesel fuel, oil, gasoline and sawdust, common to any timber operation, all have the potential for impacting fisheries.

PROTECTIVE MEASURES

Harvest

Regeneration System and Method of Harvest.- The regeneration system can have a direct, site-specific impact upon fisheries. Clearcutting, although viewed distastefully by the general public, has some distinct advantages if certain precautions are observed. Of major importance is the opportunity to reduce overall roading during the rotation. If the even-age system employs clearcutting as the harvest method, it can offer the greatest potential to reduce long-term impacts by requiring fewer entries into a given area. If necessary in highly critical areas, one entry for harvest and regeneration could be made with no interim operations. In a 100-year rotation, that could mean only one entry into the selected stands each century compared to more frequent entries necessary in the single-tree selection system. Shelterwood and group selection fall between the two extremes in relation to roading needs.

Clearcutting, in addition to reducing the number of entries into a forest, also allows a greater choice of equipment in harvest operations. As pointed out earlier, the type equipment used for harvesting significantly affects rates of soil disturbance and subsequent erosion. Where protection of stream resources is critical and land slopes are over 35 percent, helicopter and cable logging are preferable alternatives to tractor or rubber-tired skidder operations. Skyline cable systems should be selected over high lead or jammer systems when available. Helicopter and skyline operations are not economically feasible, however, for all steep-slope sales, or for the majority of thinning and selection cuts. Equipment that has a low impact, as measured in pounds per square inch of the soil surface, is a viable alternative to conventional skidders, on critical areas where cable systems are not feasible. Examples of such equipment include the tracked FMC, and balloon-tired skidders normally used for wet soil or swamp logging.

Rotation.--Lengthening rotations and reducing the number of entries reduces overall roading requirements for a given period. As previously pointed out, such reduction is a major step in the control of erosion and stream siltation.

Operating Seasons.--Operating seasons should be determined by local topography and climate. Logging should be restricted, depending upon the equipment used (cable, tractor, helicopter, etc.) during periods of wet weather.

Site Preparation.--Buffer strip criteria should apply to site preparation operations in addition to harvest activities. No mechanical site preparation should be attempted in the filter or shade strips, and no herbicides should be used in the shade strips.

Prescribed burning normally creates few, if any, problems. However, hot summer burns can destroy ground cover, resulting in significant erosion problems. As a general rule, burns during the growing season should be limited to periods when fuel moisture levels preclude extremely hot burns.

Slash Disposal.--Logging slash in streams, if excessive, creates severe problems for fishes by acting as a sediment trap, a barrier to fish migration, and reducing oxygen content of the water. Conversely, where lack of organic debris is a limiting factor, the judicious selection of a certain amount of this material to be retained in the channel could enhance the fishery. Needless to say, such selection should be guided by individuals with the necessary fishery expertise.

Transportation

System Design.--Roads should be as narrow as possible. On steep terrain, width is critical in minimizing the area of bare soil exposed in cut-and-fill slopes.

Outsloping and construction of "Coweeta" or long, gradual dips at regular intervals should be used to divert water from the roadbed. Inside ditches should not be installed if dips and outsloping are sufficient to prevent water from traveling the roadbed.

Place log landings and mill sets on ridges or points of ridges rather than in ephemeral channels or riparian areas. Such placement will reduce erosion and at the same time will reduce down time during adverse weather conditions. All roads planned for re-entry and all approaches to stream crossings should be gravelled.

Stream crossings.--Use temporary bridges in lieu of culverts on temporary roads. Excessive disturbance is created by installing culverts and the fill material required. They account for some of the more serious sources of sediment from timber sales. When the culvert is removed at termination of the sale, the disturbance created at that time again adds to the sediment load. Temporary bridges may range from two planks across a small rivulet to log stringer bridges on larger streams. Select the simplest structure needed to accomplish the objectives and simultaneously protect the resource at the same time. Ordinarily, structures consist of abutment logs installed on or in each streambank, with two or more stringers, and decking if needed. The key to reducing impact is to place the abutments where they will create the least initial disturbance, and then leave them in place at termination of the sale. Decking and stringers can be removed, if desired, when the harvesting and revegetation efforts are completed. Low water stringer bridges can be used to cross comparatively large streams to reach cutting units that would not be economically feasible to cut if permanent bridges were required. If designed properly, the stringer bridges will stay intact during major floods that often take out conventional bridges. The key to the design is that they be constructed close enough to the water surface so that only base flows pass under. The upstream stringer or stringers should be a few inches lower than the downstream stringers, thus canting the bridge slightly. This design allows all flood waters large enough to carry trees and other major debris to pass safely above the bridge. The slight cant creates downward pressure by the water on the bridge and reduces chance of flipping it out of place.

Revegetation.--The key to stabilization of disturbed areas is to establish ground cover as quickly as possible. Cut-and-fill slopes on permanent roads should be grassed during or immediately after construction. Temporary roads, log landings and other surface disturbance should be seeded and "put to bed" immediately after closure of a cutting unit rather than waiting until the entire sale is completed. To reduce the period of operating time before revegetation, and for optimum erosion protection, the cutting units should be planned as small as is economically practical. In most areas of the South, seeding can be successful throughout the year depending upon the plant species used. The common practice of limiting seeding to short periods in the spring and fall is a major factor in soil loss when sales close during other seasons. Where cutting units will be open for long periods, or operations shut down for any reason, establishment of a temporary cover such as ryegrass is highly desirable. These fast-establishing species should also be included in any mixture of permanent cover crops. Where management of wildlife such as turkey and ruffed grouse are considered, roads planted with the proper mixtures of vegetation will provide food for adults and brood range. In preparing the seedbed, ripping compacted areas and the use of mulch enhances germination and survival. The mulch, in addition, reduces problems with frost heaving.

Streamside Protection

Buffer Strips.--The term "buffer strip" is used loosely even by scientists presenting research results. Quite often it is difficult to determine if authors are referring to shade protection, erosion prevention, or both when they state that buffer strips have been very effective. For the purpose of this paper, buffer strips include both the streamside shade strip and sediment filter strip.

The effectiveness of a shade strip is determined by many factors including tree height, tree species, elevation and aspect. In general, a 10- to 20-meter wide strip on both sides of a stream should provide adequate shading even with selective removal of a portion of the canopy (Aubertin and Patric 1974, Burton and Likens 1973). Retention of a significant portion of the canopy into old growth will also ensure a source of large debris necessary to maintain a quality fishery.

Determining necessary filter strip criteria is a bit more complicated. Soil type, slope, vegetation, rainfall and amount of surface litter all have a bearing upon the extent of sediment movement. Protective criteria should address potential sediment problems in all channels, including perennial, intermittent and ephemeral, that have the capacity to carry soil. A common solution is to establish filter-strip criteria based upon slope and soil erodibility, applying only to perennial and intermittent stream channels. Such criteria may be inadequate where problems with sediment movement in ephemeral channels are not addressed. Ideally, filter-strip width should be based upon site specific conditions. When technical expertise in site-specific application of variable-width filter strips is not available, standard widths based upon slope, soil erodibility, and other factors including those listed above may be the only feasible solution. Swift (1986) suggests guidelines (table 3) for the southern Appalachians and demonstrates the value of several soil-protecting factors such as grass, mulch, brush barriers, and forest litter.

Soil disturbing activities should certainly be limited inside filter strips, but the total prohibition of heavy equipment or certain harvest techniques is not warranted. The objective should be to use the equipment and technique that will create the least disturbance on a site-specific basis.

CONCLUSION

Silvicultural activities, if administered improperly, can create severe impacts upon aquatic communities. Problems most commonly encountered include increased stream temperature through shade removal, stream siltation through soil disturbance, and reduction in availability of large, woody debris through harvest of streamside trees. Problems created by removal of large trees and other vegetation from streamside areas is a serious concern, but can be handled relatively simply and effectively by establishing guidelines for maintaining the necessary vegetative component and then implementing them. Although several researchers recommend wider zones, it appears that a 10- to 20 m wide shade strip on perennial streams is sufficiant to maintain a suitable temperature and provide the large, woody debris necessary for a quality fishery. On extremely small headwaters where volume of flow is so small that fish are not present, and rapid temperature recovery is likely, retention of only understory vegetation may be adequate.

Pinpointing the primary source of erosion and silt deposition from silvicultural activities is relatively easy. The two most evident sources are the transportation system, including all bladed roads, skidtrails, and log landings necessary for harvesting the timber, and the site preparation techniques used in revegetation efforts. Addressing siltation problems created by these operations becomes a complex issue when considering road location, road design, stream mileage, number of stream crossings, crossing design, filter strip criteria, type logging equipment, and revegetative needs. General criteria should be developed for filter strip width based upon slope, soil type and amount of debris and surface litter. These criteria should address problems with silt deposition in ephemeral channels in addition to intermittent and perennial channels. Criteria presented in table 3 should be suitable for Appalachian areas (Swift, 1986).

The following alternatives should be considered when planning silvicultural operations:

Favor cable or helicopter logging over skidders or tractor on slopes over 35 percent.

Choose skyline systems over other cable systems when available.

Consider tracked and balloon-tired skidders that have a low impact (in pounds per square inch of soil surface) on wet and steep slopes when cable systems are not appropriate.

Table 3. Minimum filter-strip width (meters) for graveled forest roads[1]

Filter strip	Percent slope								
	0	10	20	30	40	50	60	70	80
Without brush barrier	13.1	17.4	21.6	25.9	30.2	34.1	38.4	42.7	46.9
With brush barrier	9.8	11.0	12.2	13.4	14.6	15.8	17.1	18.3	19.5

Note: For prescribed burn without brush barrier or forest litter, add 9.4 meters + 2.0 meters per 10 percent slope. For ungrassed fill and unfinished roadbed in winter and early spring, double the table values.

[1] Distances are for roads with grassed banks, either outsloped or drained by ditchline and culvert onto forest floor that is covered by hardwood litter. Storm runoff that does not infiltrate into the forest soil will carry suspended clay and silt particles farther.

Reduce number of entries into the forest.

Use temporary bridges instead of culverts where possible.

Revegetate disturbed areas as quickly as possible.

Do not destroy the litter layer with prescribed burns.

Apply buffer-strip protective criteria to both harvest and site-preparation activities.

Design roads for the minimum width necessary to accomplish the job.

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Wildlife and Fisheries Management in the USDA Forest Service

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Abstract.--Forest Service policy for management of wildlife and fisheries resources has evolved in response to legislation dating back to the 1897 Organic Act. That legislative history reflects enduring public concern that National Forests be managed for multiple use. Present policy embodies concerns for plant and animal diversity, maintenance of viable populations, recovery of threatened and endangered species, and management of species in high public demand. Program emphasis and budget increased dramatically in response to the wildlife and fisheries goals stated in the 1975 Forest and Rangeland Renewable Resources Planning Act (RPA) Program. Despite further planned increases in the 1980 RPA Program, since 1980, wildlife and fisheries funding has remained constant while commodity production has been emphasized. Because of this emphasis wildlife and fisheries activities have shifted away from habitat improvement to coordination and mitigation of resource development activities. Public concern about Forest Service programs, especially logging and road building, has increased with the resulting loss of a constituency that would ordinarily support Forest Service fish and wildlife programs. The strength of wildlife and fisheries management in the Forest Service lies in developing closer ties to the user groups interested in these programs.

INTRODUCTION

The National Forest System comprises 77 million ha (191 million acres) of lands and waters presently managed by the USDA, Forest Service under the concept of multiple use and sustained yield of forest and rangeland resources. It was not always so. In 1897, the Organic Act established the purposes of forest reserves . . . "Securing favorable conditions of water flows, and to furnish a continuous supply of timber. . . ." Not until 1905 did wildlife purposes become recognized when President Theodore Roosevelt established a wildlife refuge on a National Forest. In 1911, the Weeks Act authorized National Forest land purchases to ". . . protect . . . denuded lands within watersheds of manageable streams." The protection of fisheries was specifically identified in Title III of the Bankhead-Jones Farm Tenant Act of 1937. Title III "authorized and directed" the Secretary of Agriculture to "correct maladjustments in land use, and thus assist in controlling erosion, reforestation, preserving natural resources, protecting fish and wildlife. . . ."

Throughout this period the Forest Service w was the grand old outfit that started the conse vation and "wise use" ethic of land stewardship They managed and protected the forests, the watersheds, and the wildlife for all Americans enjoy in perpetuity. To a large degree, the Service was the organizational embodiment of Al Leopold's Land Ethic. Actions were motivated b a "resource first" attitude because there were plenty of resources for all.

Then as the United States human population increased and became more mobile and affluent, the National Forests were subject to increasing and competing demands for resources. The Fores Service's ability to manage in this fashion changed. The events that initiated the change had their start with the increased wood demands during and shortly after World War II. The Forest Service did its best to meet the needs o the wartime economy. Roads were constructed an timber harvested, but in the process a whole se tor of the economy became dependent on a steady stream of raw materials from National Forest lands. There was no going back; even when othe sectors of the public voiced their concerns for other resources.

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Congressional appropriations supported by the timber resource users provided for a continued emphasis on timber harvest. During this period, however, the Bitterroot and Monongahela controversies were warning voices crying out their concerns.

As time passed public concerns resulted in development of the Golden Trout Wilderness; the Rattlesnake Wilderness; RARE I, II, and II 1/2; and the Elkhorns Wildlife Management Area. The acronyms for multiple use and environmental laws--MUSY, NEPA, RPA, NFMA, FLPMA, AND PRIA became familiar as these concerns became articulated as law. Congressional direction, under which the Forest Service managed the tremendous National Forest resources became much more prescriptive. Finally, the Mapleton Decision, access management in Montana, Forest Plan appeals, threatened lawsuits involving the spotted owl and red-cockaded woodpecker, below-cost timber sales, hard-money roads, and at the last, grizzly bear and woodland caribou appropriation use restrictions, all called into question and have redefined the priorities for National Forest resource management in the narrowest sense.

In summary, the Forest Service managing in response to Congressional and Administration direction and pressure from its timber interest constituency, found itself subject to increasing controversy and in danger of losing its broader supporting constituency. This turbulent development of policy continues today with the Forest Service striving to satisfy increasing demands on limited resources and pressure for more balanced multiple use,
and for coequal treatment of fish and wildlife resources with other resources. The Forest Service has been listening; progress is being made and attitudes are changing.

POLICY

At present the Forest Service is charged with the following minimum fish and wildlife objectives:

- Provide for diversity of plant and animal communities to meet multiple-use objectives and to preserve the diversity of tree species similar to that existing in the region.
- Maintain viable populations of all plant and animal species throughout their existing range.
- Accomplish feasible steps to recover threatened and endangered species.
- Maintain and improve habitat carrying capacity for species in public demand.

To reach these objectives the Forest Service focuses on habitat manipulation through vegetation management, while the States manage fish and wildlife populations through adjustments of bag limits and seasons. For the Forest Service, the RPA program and the Sikes Act and Forest Plans specifically define fish and wildlife objectives.

PAST PRACTICES AND DEVELOPMENTS

The historic emphasis of the Forest Service program has been on big-game habitat management to obtain greater harvests. Because of an abundance of natural habitats there was little consideration given to nongame species until the passage of the Endangered Species Act of 1973. Fisheries, despite supporting more recreational use than wildlife, and facing rapid expansion of user demand, remained a custodial program focusing more on mitigation of harm from other resource activities than on habitat enhancement to meet public demands. The basic fish and wildlife program centered on coordination with other resource developments and on a small habitat improvement program. With the completion of the 1975 RPA and Sikes Act plans came specific objectives to provide for greater fish and wildlife populations through a substantial increase in habitat management. National goals and Regional objectives were set for individual species and species groups. The Forest Service fish and wildlife budget jumped from $4.7 million in 1970 to $38.7 million in 1980. During that period fish and wildlife biologists staffing was aggressively increased to an all time high of 458 wildlife biologists and 136 fishery biologists in 1982.

Additionally, during the 1970's the efforts by biologists to quantify the effects of management activities on fish and wildlife habitats, to develop species and habitat inventory databases, to classify habitats, and to standardize inventory methods coalesced into the Wildlife and Fish Habitat Relationships System. This system relates information on habitat to the requirement of a particular species through the use of habitat capability models which can be used during land management and project planning to predict the response of a species to a proposed alteration of habitat. Habitat relationships procedures have been applied in decision processes to evaluate potential resource tradeoffs and use conflicts before they occur, as well as to assess cumulative effects of many activities spread over time and space.

PRESENT PROGRAM

After an initial accounting adjustment to separate general administration expenses from the fish and wildlife program budget in 1981, the inflation-adjusted budget has remained roughly constant despite cuts proposed by the present Administration. While staying even may itself be considered a success in these austere times, the current level of $38.8 million is about half the selected 1980 RPA program; specifically for fisheries habitat improvement, current funding is 23 percent of the 1980 RPA program. Of additional concern is that the trend toward increased fish and wildlife habitat improvement, which was started after the 1975 RPA, has been reversed as program emphasis has shifted to support and coordination of increased timber resource development activities. At present, the habitat management program is focused on mitigating effects of development activities, threatened and endangered species recovery, and on species such as anadromous fish for which there is a high public demand. Since 1980 fisheries biologist staffing has been reduced from 136 to a present level of 107, moreover, as wildlife biologist positions are vacated, the positions are not filled. It should be noted that other Forest Service programs have also decreased, however public responses to current RPA and Forest plans have called for an increased emphasis on fisheries, wildlife, and recreation.

The resident fisheries habitat improvement program ($2.0 million in 1986) can best be described as vestigial, and habitat coordination is inadequate because over 70 percent of fisheries personnel work primarily on anadromous fish resources. This emphasis persists despite the fact that resident fish support 14.7 million 12-hour days of recreational use (46 percent of total fish and wildlife use) and demand is increasing 35-50 percent per decade! National Forests contain outstanding wild blue ribbon trout fisheries as well as important warmwater fishery resources that hold tremendous recreation potential.

At present, annual funding of Forest Service fish and wildlife programs is variable and does not enjoy secure funding supported by a broad constituency of user groups. Many user groups do not support such funding because they do not know what is in the Forest Service program for them. As a result, despite detailed planning of habitat improvements and resource development project coordination to meet local demand for wildlife and fishing uses, efforts to enhance fish and wildlife habitat have been frustrated because of the need for internal and external support. On National Forest lands fish habitat capability has declined, and wildlife habitat capability for several desireable species has decreased in more areas than it has increased.

FUTURE POTENTIALS AND NEEDED PROGRAM SHIFTS

The Forest Service has the potential to develop much stronger wildlife and fisheries programs by establishing closer ties to user groups and promoting program opportunities to meet user needs. There must develop an integration of resource objectives with recreation needs. The public must see that the fish and wildlife program is not a mitigation program designed only to support commodity outputs, but one of enhancement opportunities for fish and wildlife resources that are worth investing in and managing. Forest plans and the 1985 RPA Program provide a promise of more emphasis on wildlife, fisheries, and recreation. It remains to be seen if this emphasis will be translated into reality by the fiscal process.

Coalitions of resource conservation groups have only recently begun to rally to support Forest Service fisheries and wildlife programs. Traditionally, these programs have been submerged in a larger "multiple use" resource management strategy focused on timber production. Instead of supporting the funding of wildlife and fisheries enhancements, conservation groups have focused on stopping the logging, road building, mining, and gas and oil development activities they consider detrimental to fish and wildlife resources. As a result, wildlife and fisheries efforts have emphasized mitigating and resolving conflicts. This emphasis has occurred despite growing technical expertise in restoring and enhancing habitat, and a general desire to implement Forest Plans for fish and wildlife programs in cooperation with conservation groups.

FUTURE FUNDING AND MARKETING STRATEGIES

In order to protect base program funding and increase long-term funding, the following "closed loop" funding mechanisms are proposed:

1. Establish a fish and wildlife mitigation and rehabilitation fund from resource development activity proceeds.

2. Establish access/user fees
   a. National Forest hunting and fishing permits.
   b. General recreation user fee

3. Expand the scope of the Knutson-Vandenberg (KV) fund collections to include all revenue-generating resource development activities and to include the area of effects of those activities.

4. Expand the present cooperative challenge grant approach to leveraging program capabilities by the creation of a national trust, similar to the National Endowment For The Arts, which is used to match private and state funds.

In defining a strategy to obtain political support for such "closed loop" mechanisms one must ask "who cares?" Who cares about increased habitat capability for fish and wildlife on the National Forests? The question leads to an important exercise in developing a fish and wildlife program marketing strategy. The obvious answer is, with the exception of endangered species, that the resource user cares. The recreational hunter and fisherman and the person in the supporting service and production sectors of the economy cares. The commercial fisherman, outfitter, and guide who makes his living from the resource and is also the worker in the supporting economies cares. The subsistence user who provides for his family's needs cares. The person who appreciates seeing wildlife and fish in a natural setting cares. The organizations these groups use to express their political desires (IAFWA, Audubon, NWF, TU, NRDC, EDF, TNC, BASS, DU, NWTF, RMEF) must be involved in the program as a matter of their self interest. If no organizations exist to coherently express these desires, they must be developed. In turn, the production potentials of the National Forests to meet these users' needs must be defined and the users enlisted to promote fish and wildlife programs that realize these potentials. As this political support mechanism unfolds, the Forest Service's capability to meet users' needs must be aggressively promoted along with frequent reports concerning the program results of the user groups' efforts in obtaining increases in the products they desire. Finally, the Chief of the Forest Service must communicate his commitment to respond to these user groups throughout the organization. The marketing strategy must be developed and promoted at the National, Regional, and Forest levels in order to be successful. In such a way the fish and wildlife programs detailed in each National Forest Plan can become a reality instead of remaining paper exercises.

Fisheries Management on Georgia National Forests

R. H. England

Abstract.--Fisheries management on Georgia national forests is directed toward protection and enhancement of trout streams, management of trout populations and harvest, and stocking catchable trout to help meet the demand of increasing fishing pressure. Many streams are stocked, but most are managed as wild fisheries. Stream sedimentation is a major concern but current timber and road management policies generally provide adequate protection on national forest land. The future of Georgia's trout resources depends heavily on national forest management practices, and the current planning process places more emphasis on fish and wildlife values than ever before.

INTRODUCTION

A diversity of fish species inhabits Georgia's national forest streams and lakes. Seehorn (1975) lists 158 fishes known or expected to occur within or adjacent to national forests in Georgia. This total includes game fish such as the centrarchid basses, trouts, catfishes, pickerels and various species of bream. For most of these species, the proportion of suitable habitat that lies on national forest land is extremely small compared to the statewide total. Therefore, a relatively small percentage of the state's total management efforts for most of these species is directed toward populations on national forest land. Conversely, the state's best quality trout habitat lies on national forest land and therefore management of national forest fisheries is a major part of Georgia's total fisheries program. This paper focuses primarily on the state's trout program and its relationship to current national forest land management practices.

Approximately 3,860 km (2,400 miles) of streams support reproducing populations of rainbow (*Salmo gairdneri*), brown (*Salmo trutta*) or brook trout (*Salvelinus fontinalis*) in Georgia (Fatora and Beisser 1980). About 60% of this lies within the Chattahoochee National Forest. The brook trout, the only salmonid native to the east coast, occurs only in remnant populations in some 60 small headwater streams that total approximately 130 km (80 miles). The rainbow and brown trout, introduced into Georgia before the turn of the century, had established self-sustaining wild populations in most of the remaining suitable habitat by the time the Chattahoochee National Forest was established in 1936.

Two national forests, spanning 344,291 ha (850,731 acres), are located in Georgia (U.S. Department of Agriculture 1985). The Chattahoochee National Forest covers 301,970 ha (746,158 acres) in the southernmost reaches of the Appalachian Mountains and the upper Piedmont in extreme northern Georgia. The Oconee National Forest contains 42,321 ha (104,573 acres) and lies in the lower Piedmont in the north-central part of the state. Fisheries resources on these lands con of coldwater, coolwater and warmwater streams several small lakes. In addition, national fo land borders portions of several large reservo and thus the fisheries resources of these bodi of water are influenced by Forest Service poli and practices.

By Georgia law, wild fish populations are owned by the state (Georgia Department of Natu Resources 1982), and are the responsibility o state to manage and protect. The agency char with this responsibility is the Game and Fish Division of the Georgia Department of Natural Resources. At the federal level the Multiple Sustained Yield Act of 1960 included the mana of fish and wildlife as a formal responsibili the U.S. Forest Service (Environmental Law Institute 1977). This apparent conflict in authority is resolved by a formal memorandum understanding between the two agencies.

POLICY AND PRACTICES

Trout habitat in Georgia is limited, considering that the number of anglers fishing trout is estimated at over 200,000 annually (Georgia Department of Natural Resources 1986) Most individual streams are small and producti is extremely low due to low total hardness (and Fatora 1974, Fatora 1970). Without suppl trout stocking, many of these streams would only a small portion of the present use. Ge management philosophy has been to provide a of fishing experiences, including intensive and take fisheries, artificial lures only fi and trophy trout stream fisheries (Fatora 19 but to avoid unnecessarily restrictive regul (England 1979). In practice, this had resul an intensive stocking program of catchable (9 inch) fish on selected easily accessed str coupled with a continuing effort to protect populations from habitat degradation and exc fishing pressure. In addition, habitat enha ment with log and rock stream alteration str

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as been accomplished in selected stream reaches.

Georgia's general trout regulations consist an eight fish daily creel limit, no size limit nd no bait restrictions except that live fish may ot be used. The general trout season runs from he last Saturday in March to the end of October ut a number of streams are open to fishing year round. Streams not open year around are closed night fishing. In addition, special regulations re in effect on ten stream reaches, eight of hich are on national forest land. Nine of these treams require the use of artificial lures only nd the tenth, on state park property, is stricted to use by children under age 12 and norary license holders (disabled or over age). One stream (Noontootla Creek) is managed as a catch-and-release fishery with a 41 cm (16 inch) nimum size limit. Another (Waters Creek) is naged as a trophy fishery with a 56 cm (22 inch) size limit, a daily creel limit of one fish and her restrictive regulations. Fish in Waters eek receive supplemental feeding with mmercial trout feed.

The pressure on Georgia's trout resources has steadily increased over the years. The state's population stood at an estimated 5.8 million people in 1984, with well over half of these living within a two hour drive of mountain trout streams (achtel 1985). Fatora (1983) documented that about 80% of the anglers fishing seven heavily stocked mountain streams were from the metropolitan Atlanta area. Local governments in most mountain communities are constantly looking for ways to attract tourists to generate additional income. At the same time, many of the more influential citizens are in the business of land development, real estate, banking or other growth dependent businesses. The result is a steady increase in demand for outdoor recreation, including trout fishing.

To help meet this increasing demand, the Game and Fish Division stocks catchable trout in 15 streams, small lakes and tailwaters. This stocking typically begins in mid-March and continues until the first of September. Annual stockings in these waters generally total around one million trout weighing about one-third pound each. Approximately 40% of these fish are stocked in streams and small lakes on national forest land.

Trout stocking on national forest land is limited to easily accessible areas that have historically received heavy recreation use. Restricted stocking is used to concentrate hatchery fish in areas where fishermen concentrate, thus maximizing the return to creel of stocked fish. It is also felt that this approach helps minimize the pressure on wild trout populations.

Recent creel surveys estimated a 100% return to stocked trout on five of eight intensively stocked streams, and 62% or higher on the other three (Fatora 1983). These streams were stocked weekly and total season stocking rates ranged from 4,176 to 9,476 fish/km (6,720 to 15,250 fish/mile). Season fishing pressure ranged from 3,216 to 13,719 hr/km (5,175 to 22,077 hr/mile). Mean annual catch rate averaged 0.94 fish/hr, which is comparable to the 0.86 fish/hr average on ten stocked streams in 1958-59 (England 1974). These figures suggest that increased stocking levels have allowed the state of Georgia to meet the demands of increasing fishing pressure without a decline in catch rate.

Other measures of quality fishing, such as a desire to experience solitude or a relatively unspoiled natural environment, have not fared so well. Stream banks and adjacent areas on heavily stocked streams have been heavily impacted by anglers and campers and show severe soil compaction and removal of understory vegetation. This impact has created considerable concern among forest managers, and attempts to mitigate impacts by restricting camping immediately adjacent to streams have been only partially successful. In spite of this recognized impact, these areas appear to be relatively stable, and are not causing significant stream sedimentation. However, many areas of the national forest may be approaching a practical limit in the amount of this type of use that can be supported.

Sedimentation is the single most severe anthropogenic problem affecting Georgia's wild trout fishery. Mountain soils are unstable and highly susceptible to erosion (England 1975). The popularity of the mountains as a recreation and retirement area has been accompanied by an ever-increasing demand for residential and commercial development and road construction. Georgia has a sediment control law that requires local governments to enact their own ordinances to control erosion and requires developers to submit and follow an approved erosion control plan. However, many activities are exempted and the difficulty of enforcement often results in inadequate protection for trout habitat.

While the sediment control problem is most severe on private land, a number of problems exist on the national forest as well. The multiple use concept recognizes many legitimate uses of the forest, and necessitates many compromises by managers of the various resources. For the protection of wild trout habitat an undisturbed watershed is desirable, but for timber or game management or other recreational use, varying degrees of road access are desirable.

Timber harvest and the accompanying road construction have historically caused the worst stream sedimentation problems on the Chattahoochee National Forest. Both even-age management (clear cutting) and selective cutting methods have been employed. Even-age management has received considerable criticism from environmental groups and the general public who view it as an environmentally destructive method of timber harvest. However, road construction or reconstruction appear to be the primary source of stream sediment regardless of the form of timber harvest (Patric 1976, Anderson et al. 1976). In the long run, even-age management practices probably produce less stream sediment than selective cutting because a less complex road system is needed, and any given compartment is entered less frequently for timber removal (Seehorn 1986).

Current timber harvesting guidelines used by the Forest Service in north Georgia are designed to protect streams from excessive siltation by careful placement and design of roads and the use of buffer strips along stream corridors. Such guidelines appear adequate for stream protection, but enforcement is sometimes difficult because of inadequate staff to administer each individual sale. The current land management plan (U.S. Department of Agriculture 1985) identifies major areas of the forest where management for fish and wildlife should receive priority and it mandates the use of trout as management indicator species. This approach will require the Forest Service to implement a program to monitor the effects of timber operations on forest streams.

Habitat enhancements in the form of log deflectors, cover logs and splash dams have been constructed by both the state Game and Fish Division and the Forest Service. An estimated 400 such structures now exist on the Chattahoochee National Forest. The Forest Service has recently used volunteer workers from Trout Unlimited to add additional structures. The beneficial impact of such habitat work has been debated in low productivity waters where food is the major limiting factor. However, in many of these streams there are areas with very little natural cover, and in such areas the addition of cover would appear to be beneficial. The placement of simple cover logs in strategic locations by experienced personnel appears to be the most effective form of habitat enhancement.

Fisheries management activities on the Oconee National Forest have been limited, and generally handled by Forest Service personnel. Several small warmwater ponds are managed through fertilization and aquatic weed control. Most streams in the area are small, with only limited reaches on Forest Service property. The state's management activities on public waters in this area are primarily directed toward large impoundments and are generally not directly affected by Forest Service management.

Considerable shoreline on both national forests borders several large impoundments owned by the Tennessee Valley Authority and Georgia Power Company. The Forest Service operates campgrounds and boat ramps on some of these, and thus exercises some influence on access and use. Construction of reservoir fish attractors has been expedited by the use of brush and tree tops from adjoining national forest land. These efforts have had a positive impact on the crappie fishery of Lake Nottely, a 1,692 ha (4,180 acre) TVA impoundment adjoining the Chattahoochee National Forest (Weaver 1985).

CONCLUSION

In conclusion, most fisheries management efforts on Georgia national forests are directed towards protection and enhancement of the state's trout resource. Cooperative relations between state and Forest Service management personnel a excellent. The current land management plannin emphasis used by the Forest Service to ensure stream habitat protection should help protect t national forest trout resource. In contrast, Georgia trout streams on private land are in jeopardy, and both agencies need to look for wa to promote land use practices that will protect these streams from further degradation and at t same time provide for continued public use. Th purchase of land or easements along major strea corridors, the provision of erosion control and planning expertise to county governments, and improved water quality monitoring and enforceme are areas that need to be explored.

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TREASURE Forest - Alabama's Unique Approach To Managing Its Forest Resources

Rhett Johnson

Abstract.-- Alabama's private, non-industrial landowners own almost 75% of the nearly 9 million hectares (22 million acres) of forest land in the state. A unique statewide cooperative effort by twelve state and federal natural resource management agencies has attacked the problem of low productivity and low intensity management on these and other forest lands by the implementation of the TREASURE Forest program. The program features interagency teams on the county level working with forest landowners to develop multiple use, sustained yield management plans. Landowners who successfully implement these plans are recognized statewide by an awards program. The program requires the consideration of timber, wildlife, recreation, aesthetics, watersheds, and environmental protection in all management decisions. The impact of the program on the development of Alabama's total forest resource is evident and the program is gaining in acceptance and popularity among all segments of the forest resource management community.

INTRODUCTION

Alabama contains some of the richest natural resources in the continental United States. Of its more than 13 million hectares (33 million acres), about 66% (8.78 million hectares) are classified as commercial timberland (Rudis, et al. 1984). The current Conservation Reserve Program should add another 40,500 hectares (100,000 acres) of marginal cropland to that acreage. These forest lands contain large, healthy, and diverse wildlife populations that are comparable to those of any southeastern state. Forest management varies greatly across ownership categories. Alabama's woodlands, like those of many southeastern states, are largely privately owned. Fully 94.6% of Alabama's forests are owned by private interests, with farmers owning 27.1%, forest industry another 20.6%, and non-farm, non-industrial owners 46.9%. The remainder of Alabama's forests, about 470,000 hectares (1.16 million acres) or 5.4%, are managed by various federal, state, and local governments. The controlling federal agencies include the U.S. Forest Service (3.2%), the U.S. Fish and Wildlife Service, and various branches of the Armed Forces for a total of about 4.4% of Alabama's forest lands. The Alabama Forestry Commission, the Alabama Department of Conservation and Natural Resources, and various other state agencies own about 0.6% of Alabama's forest land and other government agencies only about 0.4% (Rudis, et al. 1984). By most econonomic indices, forest industry is Alabama's largest industry (McKee 1986).

By law, most of the federal lands and much of the state lands are managed for multiple uses, and timber and wildlife fare well on these areas. Typically, forest industries in Alabama manage very well for timber production and practice a level of forest management generally beneficial to many wildlife species. In most cases, however, wildlife is an incidental product and in only a few incidences is it regarded as an income producer. Achieving that status in industry circles seems to be the key to deliberate attempts to improve wildlife habitat. Currently in Alabama, hunting rights and wildlife management are regarded by most forest industries as public relations tools that might or might not return adequate funds to recover the costs of road repair, wild fire, gates, locks, signs, and increased supervision which result from opening lands to public hunting. A few industries, notably Gulf States Paper Company, have made extensive efforts to make wildlife management an integral part of their overall forest management plans with an eye to making it also an income producer.

Without a doubt, the greatest potential for increasing the quality and quantity of Alabama's forest and wildlife resources lies in the private, non-industrial sector. Although some of the best management examples

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may be found within this group, the norm is far below that found among other ownership groups. Much of this 6.5 million hectares (16 million acres) of Alabama forest land is understocked, under-managed, unburned, and probably yielding forest products at about one-half their potential. There are various reasons for this situation, but lack of forest management knowledge and difficulty in obtaining proper assistance can often be pinpointed as the major problems.

ALABAMA FORESTRY PLANNING COMMITTEE

There are a dozen or so state and federal agencies in Alabama that provide natural resource management information and/or assistance to the general public. In many instances, duplication of effort or conflicting information has resulted from this multiplicity of sources. In 1971, in an attempt to coordinate state and federal assistance programs, 12 agencies formed the Alabama Forestry Planning Committee (AFPC) to encourage cooperation and reduce competition between the member agencies in offering assistance to the state's forest landowners. The AFPC is comprised of the following state and federal agencies: (1) Alabama Department of Conservation nd Natural Resources; (2) Alabama Department of Education, Vocational Division, Agribusiness Education; (3) Alabama Forestry Commission; (4) labama Soil and Water Conservation Committee; 5) Alabama Cooperative Extension Service; (6) chool of Forestry, Auburn University; (7) SDA-Farmers Home Administration; (8) SDA-Forest Service; (9) Alabama Agricultural xperiment Station; (10) USDA-Soil Conservation ervice; (11) USDA-Agricultural Stabilization; nd (12) Tennessee Valley Authority (Wade and oody 1983).

The committee, consisting of the head of ach participating state or federal agency, eets twice a year and formal actions are by onsensus. Despite the expected difficulties, his arrangement has proved workable. In 1976, he AFPC appointed two special committees, one o coordinate service programs and the other to oordinate educational programs. In 1983, a hird committee was created to coordinate forest roductivity programs. These three ubcommittees are made up of staff members of he various participating agencies. They meet uarterly and report directly to the AFPC.

In 1981, the AFPC requested that forestry lanning committees be formed on the county evel. These committees, comprised of the ounty-level counterparts of the AFPC members, re charged with identifying and addressing orestry, wildlife, and conservation issues in heir particular counties. Most Alabama ounties have responded by forming such ommittees. Much of the forestry activity in he state is now initiated at the county level.

TREASURE FORESTS

The AFPC has been involved in several successful programs in its short tenure, but the flagship program, particularly in regard to forest values other than timber, is the TREASURE Forest Program. The very name of the program is an acronym representing multiple use, sustained yield forest management: Timber, Recreation, Environmental enhancement, and Aesthetics for a Sustained Usable Resource. The program was conceived in 1974 and the first TREASURE Forests recognized in 1975. Since that time, about 400 forest landowners have received recognition as TREASURE Foresters.[1/]

In a typical sequence, a forest landowner seeking management assistance is identified by members of a county forestry planning committee. At that time, he is made aware of the TREASURE Forest program and urged to participate. If interested, he is asked to sign a TREASURE Forest Creed which pledges him to the concepts of multiple-use, sustained yield, and protection of environmental quality. The Creed, like the TREASURE program itself, is non-binding. The landowner's property is then listed as a potential TREASURE Forest and he becomes the target of a cooperative assistance effort in developing a management plan for his property that incorporates the precepts of the program. Ideally, the landowner would receive timber management advice from the various forestry agencies represented on the committee, wildlife management advice from Alabama Game and Fish biologists or other biologists on the committee, and general conservation and natural resources management counsel from SCS, ASCS, or Extension experts. Each landowner must identify primary and secondary management objectives chosen from among timber, wildlife, aesthetics, recreation, watershed, and environmental enhancement. After adequate progress has been made toward achieving these management objectives, the landowner may be submitted as a candidate for TREASURE Forest certification. The district TREASURE Forest coordinator, an Alabama Forestry Commission district office employee, then appoints an inspection team for an on-site evaluation of the accomplishments of the landowner. At a minimum, this inspection team must consist of a graduate forester and a graduate wildlife biologist. Other natural resource professionals may also accompany and participate in the inspection.

A detailed inspection record is completed on each property. Information recorded includes acreages, age classes, forest types, and accomplishments in the last five years in timber management, wildlife management, and/or management for other chosen objectives. In addition, forest management plans for the next five years must be prepared, indicating planned

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[1/] Letson, N., State TREASURE Forest Coordinator, Personal Communication, July 1986.

changes in land use, anticipated timber harvests, future regeneration activities, protection schemes involving salvage, sanitation, and wildfire, and the use of prescribed fire as a management tool.

The inspecting wildlife biologist must complete a checklist of accomplishments in wildlife habitat management. Questions cover prescribed burning practices, adequacy of den trees and snags, diversity of stand types and age classes, irregularity of stand boundaries, adequacy of mast production, wildlife species being managed, protection, harvest procedures, population levels, permanent openings, etc. These questions must be addressed by all landowners regardless of management objectives.

A third section of the inspection record summarizes the overall adequacy of conservation practices on the property including protection of soil, water, and air quality, with special attention paid to erosion control and stream protection. General appearance of the property is noted, although comments are generally limited to extremely unattractive situations such as open dumps. When aesthetics or recreation are management objectives, a section on accomplishments in development and management for these resources is completed by the inspection team.

The completed inspection form, with the inspection team's comments and recommendations, is returned to the district TREASURE Forest Coordinator, often with supporting documents from the County Forestry Planning Committee. Use of the property for demonstrations or other educational or research activities is encouraged in the TREASURE Forest program and documentation of such use is also often included in TREASURE Forest applications. The District Coordinator then forwards the application, inspection record, and supporting documents to the State TREASURE Forest Coordinator, a staff forester with the Alabama Forestry Commission.

The TREASURE program is administered by the Services Subcommittee of the AFPC, which is made up of the State TREASURE Forest coordinator and foresters, biologists, and natural resource specialists from several of the member agencies of the AFPC. The Services Subcommittee meets quarterly to evaluate TREASURE Forest nominations received during the quarter. Field personnel are urged to be on hand to answer questions about applications from their respective counties. The subcommittee rules on each nomination and results are returned through the district level to the appropriate counties. Applications may be approved for certification by the subcommittee, deferred for clarification or further information, or disapproved. In instances where nominations are disapproved, county planning committees and landowners are apprised of the reasons for disapproval and strongly encouraged to resubmit the application after corrective measures are taken. TREASURE Forest certification is valid for a five year period. At the end of five years, the property is reinspected to insure its continued compliance with the TREASURE Forest guidelines.

There are about 400 TREASURE Forests in Alabama containing about 202,000 hectares (500,000 acres), and an additional 500 Creed signers striving for TREASURE status.[1/] Any forest landowner in Alabama may qualify for TREASURE status regardless of ownership type. All forest land owned in the state must be considered, however, and a minimum of 4.047 hectares (10 acres) is required. The landowner receives several small awards when certified as a TREASURE Forest owner and becomes eligible for statewide recognition. The Helene Mosely Memorial TREASURE Forest Awards provide annual monetary awards to the three TREASURE Forests judged best in their respective districts and additional recognition is given to the landowner judged best in the state. At this point in the program, peer recognition and personal satisfaction appear to be the motivating factors for most TREASURE seekers. Interviews with TREASURE Foresters reveal a general concern for the land and for future generations.

It is revealing that almost 75% of the TREASURE Forest owners list wildlife as either their primary or secondary management objective. Only timber is mentioned more often, with some combination of the two being most common. Under the precepts of the program, the landowner must display numerous positive accomplishments toward his primary objective, several accomplishments toward the management of his secondary objective, and demonstrate management of his property in such a way as to minimize detrimental impacts on all other forest resources. These requirements insure that wildlife values will be at least protected on every TREASURE Forest. Although there was no intent to downplay the importance of other resource uses such as recreation and aesthetics, the TREASURE program places an emphasis on provisions for the protection of timber and wildlife resources.

An integral facet of the program is the presentation of the TREASURE award. Ceremonies with attending media coverage are strongly recommended and the resulting publicity has generated an amazing amount of landowner interest in the program. Some of the most inpassioned and effective spokesman for the program are TREASURE landowners themseleves.

All agency personnel, TREASURE Forest landowners, and TREASURE Creed signers are eligible to receive a subscription to the publication Alabama's TREASURED Forests free of charge. This attractive magazine is published quarterly by the Alabama Forestry Commission and contains management advice for all of the

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[1/] Letson, Ibid.

sources covered in the TREASURE program. It oriented toward the private, non-industrial rest landowner and contains "cookbook" type ticles by natural resource professionals from ound the state. In addition, one of the EASURE Forest families is usually featured in ch issue.

The TREASURE concept has begun to permeate e management assistance efforts of all the dividual agencies involved in the program. ndowners participating in industry assistance ograms are beginning to request more multiple e management assistance as the TREASURE ncept has gained in acceptance and popularity. ny forestry consultants use their records as nagers of TREASURE qualified lands as a lling point in their dealings with landowners. e Alabama Forestry Commission has recently ntracted with several private consultants to read the TREASURE doctrine throughout the ate. In addition, the Commission has included TREASURE Forest instructional unit in its restry Academy for all new employees. During bruary and March of 1986, the Services bcommittee provided a series of training ssions designed to educate county level agency rsonnel in the administration of the program. ese sessions were held in ten locations roughout the state and featured information on e AFPC and its programs, an overview of the EASURE Forest program, and a detailed "how-to" ssion on management for each of the resources atured in the TREASURE program. These ssions were designed to enable agency rsonnel to assist in the development of nagement plans that would lead to TREASURE rest certification. In addition, the sessions re expected to better prepare potential EASURE Forest inspectors for evaluating EASURE Forests.

The impact of the TREASURE program on the ldlife management being practiced on the rticipating forest lands is obvious. Not only wildlife often a featured management jective, the consideration of wildife habitat d welfare must be a part of every management cision. As the TREASURE Forest program grows, re acreage will be managed in this manner. ill, the acreage actually in the program is latively small and does not reflect its impact the management being practiced in the state. ny landowners and managers, although not tive participants in the TREASURE program, ve begun to adopt the concept in their nagement. General acceptance of multiple-use nagement has been increased through the ogram and through the emphasis placed on it by e member agencies of the AFPC in their eryday landowner assistance activities.

The Alabama Forestry Commission has taken e lead in implementing the TREASURE concept, t the key to the ultimate success of the ogram is the involvement of all management encies, particularly on the county level. One the highlights of the program is the preciation gained by the members of the various agencies for their counterparts in other agencies. The interdisciplinary exchanges have been particularly rewarding for all involved, increasing understanding among natural resource professionals of the management implications of the various interrelated forest resources. The interagency nature of the program makes it unique and the coordinated, cooperative effort is appreciated by landowners. Many landowners may never make it into the TREASURE program, but, as a result of the TREASURE Forest program, the concept of multiple use management on a sustained yield basis has become better accepted in Alabama as the most desirable forest management goal.

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Cooperative Research and Management for the Wild Turkey

James Earl Kennamer

Abstract.--Public interest and user demand for natural resources have encouraged cooperative and innovative approaches to natural resource research and management. Special interest groups, such as the non-profit National Wild Turkey Federation (NWTF) serve as coordinators and leaders providing the most efficient use of the expertise and monies in behalf of an important resource - the wild turkey. NWTF, through a cooperative approach, sets goals and objectives, identifies and addresses problems, encourages habitat management, facilitates restocking, transfers technology and educates people, maintains library services, and sponsors research.

INTRODUCTION

The European settlers to North America found an abundance of game birds and mammals which rapidly disappeared with subsistence harvest for food and a corresponding loss of woodland habitats as they were cleared for farming and settlements. These game populations reached an all time low during the early part of the 20th century.

In the early 1900s, concerned sportsmen initiated a conservation movement which included harvest restrictions and protection to preserve the few remaining isolated populations of such game species as deer and wild turkeys.

In the 1930s, universities, led in most cases by affiliated Cooperative Research Units and state agency biologists, began efforts to study life histories and subsequent management techniques that would provide benefits to various wildlife species. Techniques to assess habitat conditions, establish populations in unoccupied areas, and monitor individuals were necessary to provide huntable populations of game birds and mammals. As this information was put into practice, through the efforts of state wildlife agencies, the populations began to make a slow recovery.

The wild turkey is an example of a species numbering about 30,000 birds at the turn of the century, and now has reached population levels of over 2.5 million birds in 48 contiguous states and Hawaii. One of the major factors contributing to this phenomenal increase has been the reforestation of many private, state and federally-owned lands where wild trapped and transplanted birds were released and protected until huntable populations were established.

Early research was aimed primarily at life history studies and solving local problems necessary to determine the effects of potential hunting seasons. Those early studies were followed by research to improve methods of monitoring, trapping techniques, restocking efforts, and range expansion. Most of these studies were done regionally with very little contact or cooperation between states.

Now the time has come for cooperation between resource managers and users to combine their knowledge and efforts to provide maximum benefits for wildlife in general and the wild turkey in particular. Common goals and objectives, information, and practices can be achieved better through cooperative efforts.

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Land practices can be coordinated, agencies can be united in common goals, land managers and resource users can work together, and biologists and researchers can share resources and information for better wild turkey management. Unless land management is coordinated, some practices can offset the gains of another. The effects of clean farming and large-scale conversion of forests to even-aged stands can have negative effects to some wildlife populations. An example of manager/user cooperation, and an example of agency cooperation, is an agreement between the U.S. Forest Service and the NWTF to provide assistance in managing the National Forests so wildlife values will be better enhanced and the negative effects will be minimized.

It is necessary that researchers interchange ideas and expertise to avoid duplication and mistakes. Unfortunately, wildlife research efforts have been conducted with only state boundaries separating similar studies. Budget restraints at all levels demand that cooperative efforts be involved in research and management programs.

The role of special interest groups to coordinate these efforts is becoming more evident. They can unite individuals and diverse agencies, and they can cut through the red tape and politics that have encumbered game management efforts at all levels. They can achieve this through coordination and facilitation, not through usurping other agencies' responsibilities or charge.

NATIONAL WILD TURKEY FEDERATION

The National Wild Turkey Federation was founded in 1973 to work for the conservation of the American wild turkey. The NWTF is a membership-based organization composed primarily of turkey hunters affiliated into state and local chapters. The NWTF works through a national technical committee composed of biologists representing each state wildlife agency. Members of the committee meet annually and communicate regularly to keep informed of current developments, plan activities, and assess and address problem areas. This communication network has provided agencies, managers and researchers collective expertise and resources.

This year, the NWTF, with input from all segments of the organization from the chapter level to the technical committee, has launched into a program that promises to accomplish even greater rewards for the wild turkey. The program will identify major research and management needs throughout the range of the wild turkey, and second, implement a funding program to accomplish these objectives.

The technical committee has identified, and the NWTF Board of Directors has approved, seven major goals and objectives which include:

A. Encourage the conservation and establishment of wild turkey populations using best wild stock available.
B. Assist in acquisition, storage, and analysis of information and equipment needed for conservation of the wild turkey resource.
C. Encourage development of long-term research which will provide information essential to wild turkey management.
D. Encourage protection and enhancement of wild turkey habitat.
E. Encourage the sound management of wild turkey populations.
F. Promote an understanding and appreciation of the wild turkey and its needs.
G. Promote safe and ethical behavior by wild turkey resource users.

These needs have been further defined as to identify national, regional, and individual state priorities.

The NWTF Technical Committee planned and executed the Fifth National Wild Turkey Symposium when it became apparent that the every five year event was in jeopardy of being abandoned. Other workshops in North America concerning wild turkey research/management have been developed. These educational efforts have utilized the collective talents of state and Federal personnel and university scientists to provide the best knowledge available.

The NWTF committee recently completed its second assessment of the current status of the wild turkey in the United States. The 1986 Guide to the American Wild Turkey provides consolidated information concerning state wild turkey programs, from fall and spring hunting season regulations, laws, and includes individual state turkey populations distribution maps.

Recent concerns on the relationship of known commercial poultry diseases, such as mycoplasmosis, to wild turkey populations prompted the committee to undertake a program to train biologists to test for and assess diseases in wild populations, and to evaluate game farm turkeys as potential carriers. The NWTF collects mycoplasma test data from wild turkeys as reported by cooperators for use by resource managers.

The committee has developed a systematic computerized wild turkey bibliography which currently contains over 2000 references. Bibliography searches that once took weeks in a library now can be accomplished accurately in minutes. The second phase of the program is to obtain these publications for a reference library facility at the Wild Turkey Center.

The NWTF has funded 58 wild turkey research projects since 1977 which were recommended by the technical committee and approved by the NWTF Board of Directors. Over $350,000 has been granted to fund research efforts which have national implications. Examples of this research include disease assessment, habitat use, timber management and turkey habitat, effects of roads and strip-mining as they relate to wild turkeys. This figure includes $272,000 in funding, plus vehicles, telemetry equipment, nets, and other equipment purchased by the NWTF and loaned to researchers.

The Grants-in-aid Program, as well as the donation of over 20,000 wild turkey trap and transport boxes to state agencies and researchers, have both been mainstays in the commitment of the NWTF to work for the wild turkey during the last 10 years. The specially made boxes were donated by St. Regis, International, Westvaco, Union Camp, and Meade paper companies.

SUPPORT ACTIVITIES

The second part of the program is to raise the funds necessary to accomplish these goals and objectives. This unique approach is called the Wild Turkey Super Fund. Monies from direct donations and proceeds from fund-raising banquets are deposited in individual state accounts which are administered by the National Wild Turkey Federation.

Before monies can be withdrawn from a state account for a project, the project must be approved by the state chapter president, the particular state representative to the NWTF Technical Committee and the NWTF Director of Research and Management. Approval by the technical committee representative assures that the money will be spent only on projects that will benefit the wild turkey resource. Coordination through the national office makes sure monies will support goals and objectives as approved by the NWTF Board of Directors and the accountability of the money is maintained.

CONCLUSION

The cooperative approach to natural resource management is necessary to protect our resources and meet future management objectives. Private organizations can serve as cooperators, facilitators, fund raisers, lobbyists, and educators. They can interact positively or negatively with other agencies in the best interest of the resource as situations dictate. More than ever before, we must work together to protect our wildlife resources as we face the challenges of the future. Anything less will be a disservice to what so many have worked for in the conservation movement.

Wildlife Management By Champion International Corporation

Charles E. Allen

Champion International Corporation is developing a multifaceted wildlife program aimed at integrating wildlife and forest management. The program includes: (1) forest management prescriptions to accommodate wildlife, (2) developing land classification and fee access systems and (3) cooperative research to test wildlife management practices. Champion leased approximately 626 thousand ha (1.55 million ac) in the South in 1985. Income varies per ha depending on region and tract desirability. Wildlife management is funded mainly through hunting lease fees generated primarily from local hunting clubs. Indirect returns include customer entertainment on Company lands, promotion of a positive public image and public recognition for its wildlife management practices.

INTRODUCTION

Commercial forest land in the United
tates is estimated at 195 million ha (482
llion acres). Approximately 72% is in
rivate industrial and non-industrial holdings,
nd 28% is publicly owned (American Forest
nstitute 1982). Land uses such as urban
xpansion and reservoir construction (etc.) are
liminating wildlife habitat in the commercial
orest land base by .4 to 1.2 million ha (1 to
million ac) per year (Tomlinson 1985). The
rrent demand for outdoor recreation promises
intensify. A 66% increase in demand for big
me hunting is expected by 2020 (USDA Forest
rvice 1975). The result has been over-
owding on public land and increased pressure
d problems for the private sector.

CHAMPION'S PROGRAM

Outlined in this presentation are Champion
ternational Corporation's wildlife management
actices on approximately 2.63 million ha (6.5
llion ac) nationwide. It is hoped these com-
nts will be useful to other private land
nagers.

Wildlife and outdoor recreation opportun-
ies discussed here will focus on game species
d activities that generate user fees and
come for their management and continuance.
ampion recognizes the importance of non-game
imals and nonconsumptive recreation such as
otography and observation however to date,
ly consumptive users have provided monetary
pport for management.

Fiber production is the primary purpose for Champion's land ownership. Wildlife and fish are also important renewable natural resources. After purchasing St. Regis Corporation in 1984, Champion appointed a wildlife programs manager and expanded wildlife operations nationwide.

Timber Management and Leases

Corporate policy states that Company land will be managed for multiple uses. While environmental concerns and promotion of a positive public image are very important, economic justification for wildlife management guidelines is through access fees. Champion promulgates guidelines addressing subjects such as riparian zones, clear-cut size, shape and distribution, and retention of hardwood areas.

Although management varies somewhat by region, land managers in each region are encouraged to protect important wildlife habitats surrounding major streams and drainages and to consider altering the shape and size of clear-cuts to benefit wildlife when possible. Protected riparian zones average from 15 to 61 m (50 to 200 ft) wide. Clear cuts are recommended to be 81 ha (200 ac) or less, irregular in shape with a 5 year age differential to the adjacent stand.

White-tailed deer are a primary game species for hunters in the southern forest. In order to recommend deer management

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procedures, Champion has initiated a computerized data system designed to maintain records of animals harvested on each lease. Lessees, especially those with tracts 405 ha (1000 ac) or more, are encouraged to collect biological information from all harvested deer. Data include field-dressed weights, age, antler measurements, sex, and lactation condition in doe deer. These data are collected by the district offices across the South and are forwarded to Huntsville, Texas for computer analysis. Each lease is sent a summary indicating average weights and antler measurements by age class as well as computer generated graphs comparing these data with previous years. Statistical tests comparing years or adjacent leases can also be performed. This data, combined with deer census information and forest management plans, form the basis for the wildlife plan for each area.

Land Classification and Fee Access Systems

Access fees are realized primarily through leasing to hunting clubs. Champion leased 626 thousand ha (1.55 million ac) from a total fee acreage of 1.05 million ha (2.59 million acres) across the South in 1985. Leasing additional acreage is being initiated or intensified.

Wildlife surveys of Company land indicate leased areas support higher and more diversified game populations than unleased holdings. Lessees develop a surrogate ownership behavior pattern conducive to protection from poaching, trash dumping, arson, and vandalism. These reasons, coupled with economic incentives, are providing the impetus to develop fee access programs in unleased holdings. For example, a 45,000 ha (111,200 ac) free permit area in Washington State adjoining Mt. Ranier National Park is being studied as a potential fee permit area. Campsites, firewood, and hunter check stations are now provided. Hunter management includes designating areas where only walk-in hunting is permitted. Spotlight and helicopter census information as well as biological data from hunter kill provides population status and animal quality data. A contract security man is provided to patrol the area for trespassers and game violators. Cooperative wildlife management with the Washington Department of Game is being studied to produce older aged-class elk (Cervis canadensis) and black-tailed deer (Odocoileus hemionus columbianus) to develop higher animal quality.

Differences in habitat quality and game species diversity affect desirability of various tracts available for leasing. The purpose of our investigating a land classification system is to objectively quantify these differences so that tracts are equitably priced for both the lease holder and Champion. Five different classifications were devised based on a point scoring system. Points are awarded for habitat and wildlife species diversity, hunter accessibility, tract size, site index, and presence or absence of water including fishing opportunities. Conditions that negatively impact the tract's attractiveness are also considered and points are subtracted from the total for adverse situations. Classification categories are expressed as Class 1 through 5. Ranges are 181-225 for Class 1, down to 0-55 for Class 5 land. Prices vary by region but range between $.50 to $5.00 per acre. The system is being tested in selected areas this year. Corporate policy is that local sportsmen shall be given preference in leasing with fees at or below fair market value.

Test Practices and Cooperatives in Research

The Brushy Creek Experimental Forest in eastern Texas is used for forest management, wildlife research and management, and customer and guest hunting entertainment. Forest management consists of a 25-year pulpwood rotation, clear-cutting, site preparation and planting, prescribed burning, and protection on riparian zones. Special practices for wildlife include prescribed burning 5-10% of the area each year and planting chufa, oats, wheat, and clover for turkeys and deer on about 1% of the area annually. Logging operations have been suspended during spring in turkey's nesting areas and regular patrolling of the area and limited access to the public appear to limit illegal hunting.

Wildlife management and research on Brush Creek are directed at eastern wild turkey (Meleagris gallopavo silvestris) and white-tailed deer (Odocoileus virginianus). Thirty-two wild-trapped turkeys were released on Brushy Creek in 1979. These birds were radio tracked from 1979 to 1983 by Texas A&M University to determine forest habitat use patterns. Information from this study has contributed to knowledge of habitat requirements. Reproduction from this population has been used to restock unoccupied habitat in eastern Texas. More turkeys have been trapped and transplanted from Brushy Creek than from any other East Texas restoration area. This population will continue to be of paramount importance in restocking efforts.

Prior to 1971, Brushy Creek was open to unrestricted hunting and cattle grazing. The area was posted in 1971 and hunting was prohibited until 1977. Grazing has been discontinued since 1977, the deer management emphasis has been to produce and harvest quality deer. Management to accomplish this goal includes maintaining the herd at or below carrying capacity, harvesting at least an equal number of does and bucks and harvesting spike bucks. Census work is performed using spotlight and helicopter techniques. Buck age-class management is by rotational hunting. Brushy Creek is divided into three management units, each approximately 3,100 ha (7660 ac) in size. All areas are hunted for spikes and doe deer depending on the population, but branched antlered bucks are hunted only in one area each year. All hunting is performed by customers and guests. Each unit is not hunted again for three years to allow a higher buck age-class distribution to develop.

This procedure has proven effective. Data from five years indicate that 32% of the bucks harvested have been 4.5 years old or older. A typical 4.5 year old buck from a sample of 46 from Brushy Creek weighed about 49 kg (109 lbs) field dressed, with an inside antler spread of 38 cm (15 in), average base circumference 11 cm (4.3 in), main beam length 51 cm (20 in), and had 9.2 points. From 1977 through 1981, data were collected on 144 bucks harvested from Brushy Creek. Measurement data from these bucks were compared to those of 406 bucks harvested throughout the Pineywoods ecological region and to data from 795 bucks measured in storage facilities in the South Texas Plains ecological region. Deer from Brushy Creek had similar weights but generally had larger antlers than the deer from South Texas.

Cooperative Research and Management

Cooperative research has been conducted with U.S. Forest Service's, Wildlife Habitat & Silvicultural Laboratory (WHSL) in Nacogdoches, Tx. These cooperative projects have proven beneficial from several aspects. Champion obtains information that can be used in practical management applications. The wildlife lab benefits from consultation on experiments, assistance in applying treatments, use of company land, and from information it obtains from Company biologists regarding research needs. Research results also directly benefit the wildlife resource through improved management techniques and ecological understanding. Studies and cooperative work have included economic and biological aspects of green-tree reservoirs (Allen and Halls 1978), dispersal, reproduction, mortality, and habitat utilization of restocked eastern turkeys in East Texas (Hopkins 1981), and development and impact of an industrial wildlife program (Allen and Dickson 1983). Current projects with WHSL include a study comparing hunter success and deer sightings in 10-20 year old pine plantations versus other habitat types.

Management goals of the various state wildlife agencies and Champion are similar in many instances. Wildlife personnel for Champion stress the importance of antlerless deer harvest and other wildlife management techniques to hunting clubs. State biologists and law enforcement personnel are frequently contacted by Champion's personnel developing a positive working relationship. For example, as a result of a proposal by Champion's Wildlife Programs Manager, Champion and the Texas Parks and Wildlife Department are cooperating to analyze the effects of pre-season antlerless deer harvest in East Texas for the 1986 hunting season.

Champion is cooperating with the Montana Fish, Wildlife, and Parks Department on a big-horn sheep restoration effort and investigating cooperative efforts with the Washington Department of Game on aerial census and cooperative management programs for elk and black-tailed deer.

Other cooperative working relationships have developed between wildlife agencies or organizations and Champion. Champion's Wildlife Programs Manager serves as chairman of the Private Lands Committee of the Southeastern Section of the Wildlife Society and works closely with the Wildlife Management Institute. Champion's Wildlife Programs Manager for Texas is involved with the Texas Forestry Association's Wildlife Committee and implements wildlife management activities in Texas.

Customer and Guest Hunting

Product sales and marketing are the heart of any manufacturing company. By offering customers and guests the opportunities to hunt on the Brushy Creek Experimental Forest, the company generates customer goodwill and increased product sales, while maintaining strict control of hunting methods, hunter kill, and biological data collection.

Public Relations

Champion's involvement in wildlife management and research has appeal to many hunting, conservation, and environmental groups. This involvement is publicized by outdoor writers and the news media through the efforts of the Company's Wildlife Programs Manager and its Public Affairs Department. The Company and its wildlife personnel have been recognized for their conservation contributions by the Texas Forestry Association, Safari Club International, Sportsmen's Clubs of Texas, the Texas Outdoor Writers Association, and the Soil Conservation Service. While difficult to measure, these indirect benefits may be even more important to Champion than direct returns from lease hunting.

CONCLUSIONS

Managing the wildlife resource on industrial forest land in a professional manner is providing both direct and indirect returns to Champion. Direct returns are realized primarily from leasing fee access to hunting clubs. The company has successfully implemented programs that help lease holders collect and analyze biological data to improve their recreational experiences. Cooperative management and research efforts between Champion and federal and state wildlife agencies have proven beneficial. Indirect returns include a wide range of benefits, including customer entertainment on wildlife management areas, promotion of a positive public image, and recognition for environmental enhancement.

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Summary and Concluding Remarks

Dan W. Speake

Today's speakers have emphasized that opportunities for wildlife and fish management on southern forests are good and improving. The reasons given for this fortunate state of affairs were several. McKee has shown that landowners can expect profits from timber-wildlife management programs to exceed profits generated from timber alone. Annual fees for the lease of hunting rights have been increasing to the point that it certainly pays for a landowner to consider lease hunting as an annual source of income from forest land between the time of tree planting and harvest.

At the same time the technical information that is needed for the integration of wildlife management with timber management is improving. This information helps the forest manager justify wildlife management practices. R. Johnson has shown how the Treasure Forest program is organized to get technical information out to the persons that actually control the land use of 75% of Alabama forest land. Kennamer has shown us how a special interest group, The National Wild Turkey Federation, has begun to help finance and coordinate research, management and education efforts on a nationwide scale.

Still another positive factor is the improve- ent in cooperative attitude between the various atural resource groups. Ellis reminded us that isputes between foresters and wildlife and fish rofessionals over priorities are legendary. Most f the speakers have stressed that cooperation is enerally good at this time. Allen said that ublic recognition may be even more important than he direct returns. His company has cooperative orking relations with state and federal agencies, utdoor news media, universities and others. hampion's activities include collection and nalysis of data from hunting clubs, support of esearch and promotion of wildlife management. unting lease fees from company lands support this rogram. Several other industrial forestry compa- ies operating in the south have similar programs. ne U.S. Forest Service has a mandate to manage for ultiple use of all resources on the public lands nder its control.

We could go on pointing out areas where fores- ers and wildlife and fish managers have interests hat are the same but of course there are places here the different values cannot be well managed or at the same time. We cannot have multiple use verywhere, at least not on private land.

I'm sure that most foresters would prefer iversity, abundant wildlife and fish and aesthe- ically pleasing surroundings if they can bring bout such conditions without having to pay too igh a price. On the other hand, as S. Johnson ointed out, wildlife professionals have come to see that not all pine plantations are "biological deserts" throughout the rotation and that commercial forestry is much better wildlife habitat than strip mines, large agricultural fields, or subdivisions. When it comes to prescribed burning, Landers stated it well, "prescribed burning is perhaps the most under-utilized but valuable tool available to wildlife managers." Current knowledge of the use of fire for both wildlife and forestry purposes is such that both foresters and wildlifers regard it as an under-utilized tool. Another much under-utilized tool is thinning. Frequently thinning benefits both timber management and wildlife management; in fact there are many situations where burning without thinning is of little value to wildlife habitat.

As hunting and fishing lease holders pay more money and learn more about management techniques that affect wildlife and fish, they will be putting more pressure on foresters to modify some of their practices to benefit wildlife and fish. S. Johnson pointed out the tendency for less intensive timber management on marginal sites which can be beneficial to some species. It might prove more desirable and profitable in the long run to manage some mixed or hardwood stands that have good wildlife value with a selective cutting or group selection system that maintains wildlife habitat values and timber values continually. Some areas such as deep sand ridges and bogs, that often are poor timber sites, could receive special consideration because of their value to rare, threatened or unique plants and animals.

I was much impressed with the comments of various speakers regarding the importance of riparian zones. What emerges from the presentations of Dissmeyer, S. Johnson, Dickson and Huntley, E.L. Miller, Seehorn, and England is that essential fishery values such as food production, water temperature, sediment control and stream flow regulation are protected by almost the same actions recommended for protection of soil productivity, provision of diversity, and retention of the mature forest component for mast and fruit production, travel lanes, and essential habitat for squirrels, turkeys and some non-game species. Surely most of us can agree on the importance of riparian zones, but further research is needed to clarify their values to key wildlife species and to determine how wide they should be for specific purposes. This type of information is especially needed to improve the management of wild turkeys and is being acquired by Dickson and others.

Lest we paint too rosy a picture, it should be acknowledged that many problems exist and many improvements could be made. One problem that has worried me for years is the possibility of severe restrictions on burning that could come about due to public pressure.

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. 36849.

Well-meaning, but ill-informed, pressure groups sometimes act as though they believe that all fires are environmentally destructive. Demonstration and education or re-education will perhaps take care of that. There is the nagging possibility that lawsuits from road accidents caused by smoke or other smoke problems will lead to such restrictions that burning will be practically banned. With the conversion of many upland mixed forests to pine types having a naturally lower wildlife value, we have become more and more dependent on the burning tool for wildlife management. It would be disastrous to wildlife values if we could not use it.

Vegetation control with herbicides can be used to benefit some wildlife species at the same time it benefits timber. However, some of the goals stated in the newspapers by proponents of herbicide use tend to alarm wildlife biologists, hunters, fishermen and nature lovers. If it becomes possible or economical to really remove herbaceous growth from pine plantations for more than a short time or to eliminate woody plant rootstocks altogether from pine plantations then serious conflicts would develop. As McComb and Hurst pointed out, the effects of herbicides on wildlife species reproduction and survival need more research. Even though toxicity levels of the commonly used compounds appear low, we need to be sure of the possible long-term effects on non-target organisms. Land managers that value the use of herbicides as tools should not forget the recent controversy in which the use of 2,4,5-T was lost.

I think that J. Miller is entirely right in criticizing the wildlife community for not adequately encouraging and supporting research and education programs in animal damage control. Wild animals not only sometimes seriously damage timber values but also can limit populations of other preferred and threatened animal species. Where beaver control is necessary it can sometimes be accomplished by organizing trappers in problem areas. Part of the inducement can be permission to take other furbearers such as raccoons, foxes and bobcats. The latter group of species along with wild dogs are frequently important limiting factors on populations of such species as wild turkeys and gopher tortoises. Since man has removed many of the checks on furbearer species and his land management frequently helps bring about an increase in their numbers, he sometimes has to assume responsibility for balancing things.

Free public hunting as we have known it is on the way out. If it becomes economically feasible to manage land for wildlife, then it becomes economically unfeasible for the hunters to have a free ride. To me it is an obvious truth that as wildlife values increase because of rising demand and investments in management, more and more lands will be closed to the general non-paying public. One hears a good deal of grumbling now about, "out of state hunters leasing up all of our land." For some reason the protest is almost always directed toward out of state hunters, but regardless of who leases the hunting rights, some people will be forced out of traditional hunting grounds. For a time there will be trouble over this and public wildlife management areas and other public lands will be heavily impacted. It may become necessary for the state wildlife management areas to increase user fees as suggested by Brouha for the national forests, not only to have funds for management, but to keep private lands in the existing management areas. Ways must also be found for the states to acquire additional lands for public wildlife management areas and for direct habitat improvement to become a better supported activity on national forests.

Many of the speakers today referred to the necessity for site specific evaluations that must be made by individuals with the necessary judgment and technical expertise. As S. Johnson stated, "the responses of vegetation and wildlife to silvicultural practices may differ drastically at different places and different times. Blanket prescriptions don't work everywhere." As the economic values of wildlife and fish increase, the opportunities will likewise increase for skillful practitioners of the art of wildlife management. Good, experienced field ecologists and wildlife managers are in short supply, and many of today's wildlife training programs are not emphasizing management Managers in the field are frequently moved about so much that they do not get enough on-the-ground experience to develop expertise for a particular environment, or they end up in an office. I believe that foresters should have some training in plant taxonomy and plant ecolog to include lesser vegetation as well as trees. Wildlife biologists should be exposed to enough forestry training to at least be familiar with silviculture and have some understanding of the economic reasons for forestry practices.

All of today's speakers referred to the nee for research to further define the requirements of wildlife and fish and their responses to management practices. They cited many examples of successful research in recent years and called for additional work to solve specific problems. Recent advances in technology have improved research tools, for example we now have much better radio telemetry equipment for tracking animals than was available just a few years ago. Solutions to many problems will be forthcoming when research is better funded. Thi is especially true for the non-game and threaten and endangered species which have not been well studied as a group. One of the reasons for this has been that financing has not been as availabl for research on these species as it has for research on game and sport fish. Sportsmen deserve a great deal of credit for their support of game and fish species, and other interest groups should follow their example. So far most of the research on nongame species has been financed by public agencies but I might mention a notable exception in this region. The International Paper Company (IP) recently spent money to investigate the ecology of the lowly gopher tortoise, a species that is of interest to a relatively few very enthusiastic people. The work was extremely well done and IP was presented with an award by the Gopher Tortoise Council. The affair of the gopher tortoise is not over since it turns out that thi species is crucial to the welfare of several rare and at least one threatened species and the tortoise itself is now a candidate for listing as threatened in the western part of its range. There is now a demand for technical information on management of this species that has been supplied in large part from the efforts of IP.

Much more research is needed along the lines of work being done by Tall Timbers Research Station, a private organization located near Tallahassee, Fla. Tall Timbers is involved in Long term studies of Southern Coastal Plain ecosystems. They are responsible for much of what we know about the role of fire in coastal plain pine forests. It takes years of study for many of the ecological relationships that form the basis for forestry and wildlife management to be worked out. Short term applied research will not do the whole job.

It might be well for us to consider that technology will not solve all our problems. Some of the most serious ones are social. Natural resource managers deal with a public that is frequently poorly informed but still determined and vocal. Our peculiar system where most of the land and timber is privately owned and the wildlife is state owned can lead to conflicts and controversy unless strong trespass laws exist and can be enforced to protect the rights of the landowner in marketing the opportunity to harvest the wildlife.

In spite of the problems, there is a great potential for wildlife management on southern forests. With the economic value of hunting and fishing opportunity now increasing, I am looking forward to a bright future for these natural resources.

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Dickson, James G., and O. Eugene Maughan, editors. Managing southern forests for wildlife and fish --a proceedings. Gen. Tech. Rep. SO-65, New Orleans, LA; U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1987. 85 p.

Papers from a technical session working group of the 1986 Society of American Foresters national convention. Topics include economics of accomodating wildlife and fish, impact of specific forestry practices, special techniques, and prospects for the future.

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Seed Biology and Technology of *Quercus*

F. T. Bonner and J. A. Vozzo

April 1987

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Seed Biology and Technology of *Quercus*

F.T. Bonner and J.A. Vozzo

INTRODUCTION

The genus *Quercus*, known as oak, includes worldide some 500 species with 58 of these species in the nited States, making it this country's largest genus native trees (Little 1979). Oak is therefore an imortant group of temperate-zone forest trees. In addion, oaks are significant components of many of the ajor forest types of the South (Burns 1983) and are e most commercially important hardwood genus. ed and white oaks together account for nearly half 6 percent) of the annual hardwood sawtimber harested in the South (U.S. Department of Agriculture 982). They also comprise about the same percentage the sawtimber and growing stock occurring on comercial forest lands.

Although a majority of southern nurseries grow me oak seedlings (Monaghan 1984), both their proiction and customer demand are low. Some forest dustries grow seedlings in their nurseries to refort their own lands, but no widespread planting of oak edlings occurs presently in the South. Natural reneration, both from seeds and from sprouts, most ten establishes stands. Recent successes in direct eding (Johnson 1984; Johnson and Krinard 1985; nningham and Wittwer 1984; Francis and Johnson 85) have stimulated interest in this very promising ethod of regeneration, which requires large ounts of acorns.

Research on the seed problems of southern oaks was nducted from 1967 to 1983 at the Forestry Sciences boratory, Starkville, Mississippi. This paper sumarizes in two parts the results of that research, inrporating both published and some unpublished relts. Part I reviews current biological knowledge of orns. Part II recommends handling and managent techniques for acorns of southern white and red oks.[1]

Part I. Current Biological Knowledge

TAXONOMY

Taxonomically, *Quercus* belongs to one of two families in the order Fagales. Fagaceae, the beech family, has four other genera in addition to oak; *viz*., *Fagus* beech; *Castanea*, chestnut; *Castanopsis*, chinkapin; and *Lithocarpus*, tanoak (Little 1979). Within the genus, North American oaks are further subdivided into two subgenera, *i.e*., *Lepidobalanus* (white oaks) and *Erythrobalanus* (red and black oaks).[1] The other Fagales family, Betulaceae, is the birch family.

Oaks are dicotyledonous, monoecious, with fruit development characterized botanically as nuts. The nuts, commonly called acorns, are usually associated with an involucre forming a cup around the mature fruit. The acorn contains one seed and has a straight embryo with no endosperm. Although oak morphology is discussed later, these characters are necessary for its taxonomic determination. Engler and Prantl (1924) suggested that these characters represent a primitive evolution; however, Benson (1957) related *Quercus* to a much more sophisticated order, Rosales.

The white oaks have rounded leaf tips, smooth acorns borne on current year's twigs, and light-colored bark. Their acorns mature in the year of fertilization and are usually non-dormant. Red oaks have pointed leaf tips, hairy acorns on second-year wood, and darker bark (Schery 1958). Their acorns usually require 2 years for maturation, and many species exhibit dormancy.

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[1] Throughout this paper the term "red oaks" is meant to include all red and black oaks of the subgenus *Erythrobalanus*.

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ANATOMY

Acorns develop from an entire ovary with resulting ovary walls hardening into the pericarp; by definition they are hard, one-seeded, dry, and indehiscent fruits. Other common examples of this type of fruit are chestnut and hazelnut (Holman and Robbins 1944).

Between the earliest report of *Quercus* embryo and fruit morphology by Hartig (1851) and the recent work by Mogensen (1965), the development of acorn anatomy has been investigated by relatively few researchers. For a literature review and concise descriptions of *Quercus* embryogeny, readers should refer to Brown and Mogensen (1972) and Mogensen (1973).

A diagrammatic median section of a typical mature but not yet germinated acorn is seen in figure 1. Note the relative areas of embryo axis to cotyledon before germination. Pericarp completely surrounds the entire structure and is the remnant of its ovary wall.

The comparative anatomy of dormant, stratified, and germinating oak embryos facilitates an understanding of structural changes necessary for seedling generation. Progressing from the mature dormant state through the vernalization of pretreatment leading to germination and growth, an acorn must have a concomitant development reflected by dynamic tissue changes. These anatomical maturations have been characterized using light and electron microscopy, supplemented by histochemical staining.

The following descriptions are presented in detail in Vozzo (1974), Vozzo and Young (1975), Vozzo (1978), and Vozzo (1985).

In dormancy, the acorn has a small embryo axis surrounded by well-developed cotyledons and a continuous layer of epidermis (figs. 1 and 2). During stratification (fig. 3), the embryo polarizes, then elongates into an evident shoot apex and root cap. Its shoot apex has generative rib and peripheral meristems. The cotyledons appear similar to the dormant state, but there are great physiological differences. After germination (fig. 4), the embryonic axis has fully elongated to form the hypocotyl rudiments. A well-defined transitory region separates the axis centrally into cortical and stelar zones.

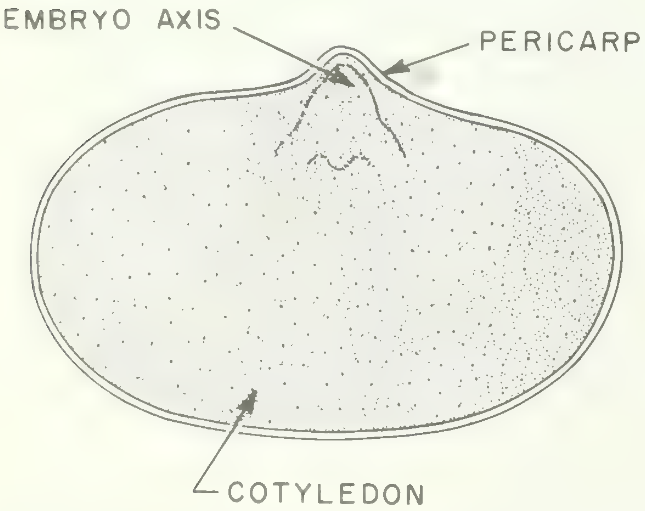


Figure 1.—*Diagrammatic median section of a typical mature acorn, showing the cotyledon, embryo axis and pericarp.*

Nucleoli in the dormant cells have a more uniformly dense structure than in a simple nucleonomatic bundle. Nucleoli are also seen with small buds attached. Nucleolar budding is absorbed in germinated embryos, but never seen in ungerminated, stratified embryo cells. Cells of germinated embryos have variable nucleolar densities with either light or dense centers as described by Srivastava and Paulson (1968).

All conditions are characterized by rough, granular endoplasmic reticula near both lipid droplets and mitochondria. Both single endoplasmic reticula and parallel stacks appear in stratified cells. No stacked reticula occur in dormant cells. The endoplasmic reticula associated with germinated cells are always distinguished by inflated terminal vesicles, which are larger and appear to form vacuoles (Poux 1961). The stacked reticula seen in stratified and germinated cells confirm reports by Villiers (1971) that this is a sign of maturation.

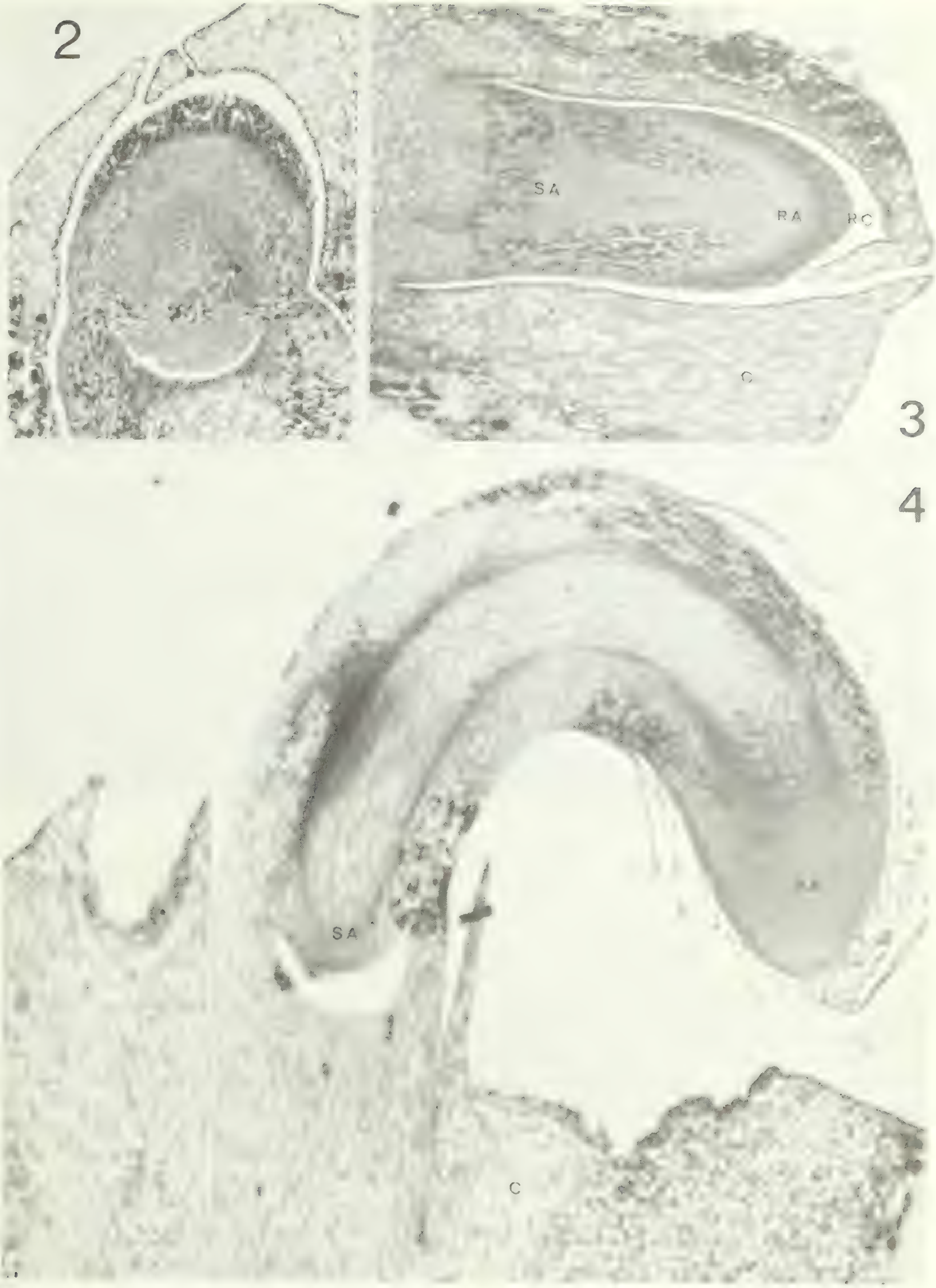
Mitochondria also reflect the changing metabolism as acorns move from dormancy to germination. Few and poorly developed mitochondria are seen in dormant embryo sections. Numerous, well-developed mitochondria are found in stratified cells, however, and as the respiratory demand increases, germinated cells show mitochondria with a nearly solid matrix.

Unlike mitochondria, dictyosomes diminish in oak embryos progressing from dormant to germinated cells. Klein and Ben-Shaul (1966) attributed dictyosome absence in lima beans to metabolic demands during seed maturation, and oaks may behave in a similar fashion.

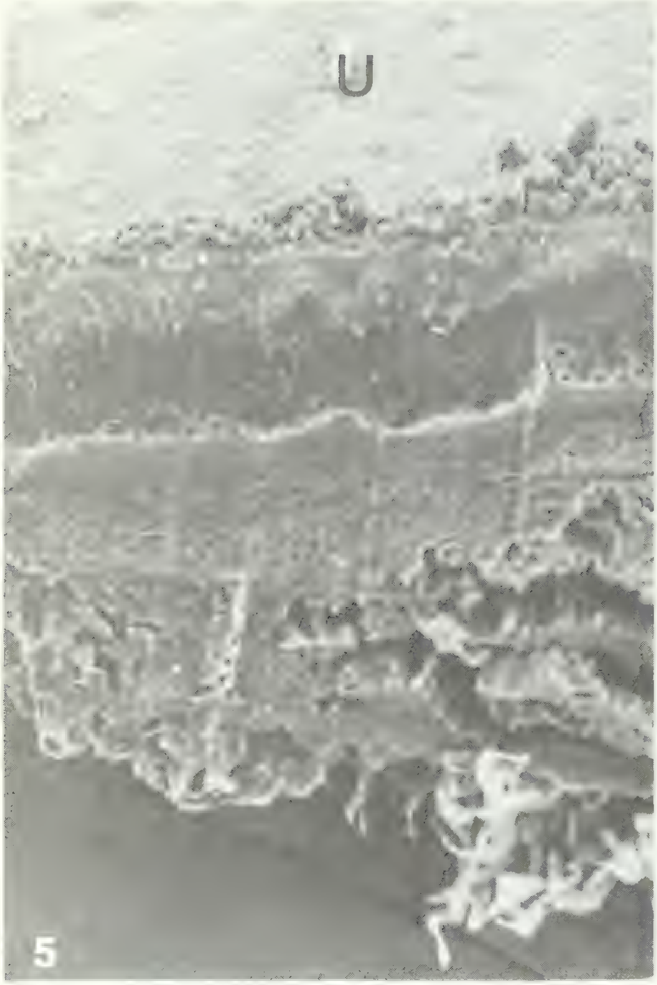
The primary cell wall remains about the same from dormancy to germination. Small dense bodies, perhaps lipid accumulations, appear adjacent to the cell wall in dormant and stratified acorns (Klein and Ben-Shaul 1966).

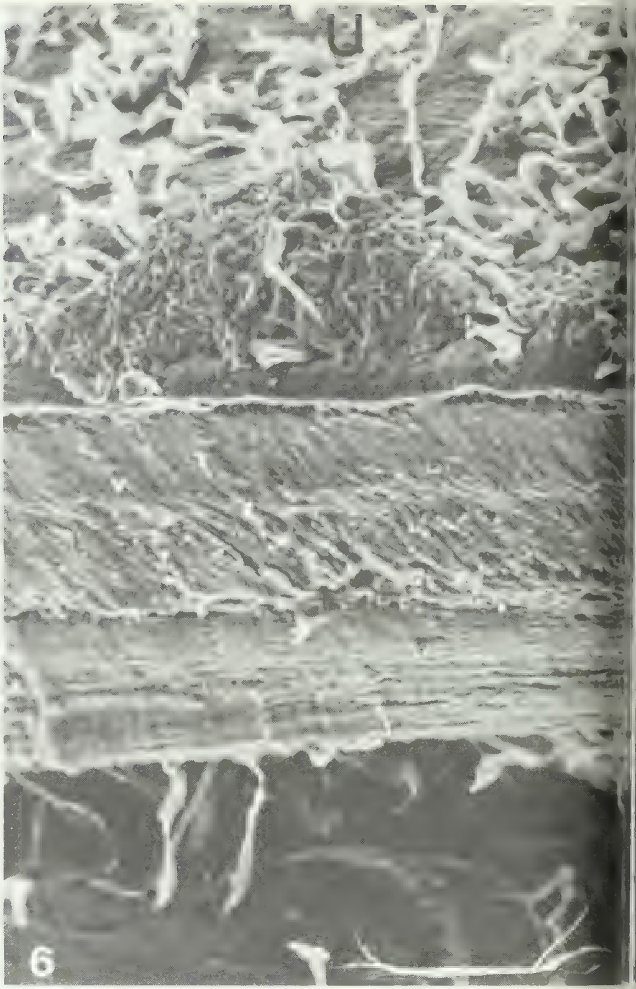
Another trend is the presence of microtubules. Rare in dormant cells, common in stratified cells, and less frequent again in the germinated cells, microtubules are generally associated with shaping plant cells.

The pericarp of water oak has three distinct layers visible on careful dissection: a sclerified exocarp; a striated mesocarp; and a fragile, thin coriacous endocarp. The endocarp layer (plus adjoining seed coat), distinguished in fresh samples by its thin, brown, leathery appearance contrasted against the yellow, succulent cotyledon, usually tears away during dis-



Figures 2–4.—*Median longitudinal sections of water oak embryo and cotyledon (C, cotyledon; RA, root apex; RC, root cap; SA, shoot apex). Fig. 2, dormant; Fig. 3, stratified; Fig. 4, germinated. (All figures × 32.)*





Figures 5–7.—*Pericarp sections of water oak acorns (U, unidentified spore-like structure; H, hypha-like strand). Fig. 5, dormant; Fig.*

section and is difficult to see in prepared sections.

Surface textures of pericarps from dormant and germinating acorns are different. The exocarp in dormant acorns has an unobstructed, undifferentiated surface, broken occasionally by undetermined spore-like structures (fig. 5). These unidentified structures suggest the origins of hypha-like strands which appear later during the stratification process and then become commonly associated with the germinated seed. Their appearance becomes obvious during stratification (fig. 6). A profuse network of strands develops, following the contour of the exocarp surface. As germination progresses, additional strands of the network loosely envelop the outer layer of the pericarp by the time of radicle emergence from the acorn (fig. 7). These strands do not penetrate the sub-surface. A progressive decrease in density of the pericarp layers appears also to accompany stratification and germination. These changes suggest increasing permeability of the pericarp, but the pores and tubular channel are not conclusive evidence of a translocation system However, they do represent potential pathways fo gas and water exchange through the seed coat. Thi interesting aspect of acorn anatomy deserves furthe study.

METABOLISM

Concomitant with tissue differentiation and enlargement is a complex chemical transition withi the embryos. Substrates, metabolites, and pooled reserves are continually in flux. Research at Starkvill has focused on one species from each subgenera. *Q nigra* (water oak) represented the subgenus *Erythrobalanus*. *Q. alba* (white oak) represented th white oak subgenus of *Lepidobalanus*. It is likely tha other species within each subgenera share the sam general metabolism.

s atified; Fig. 7, germinated. (All figures × 200.)

aturation

Water Oak.—Acorns steadily increase in size and f sh weight from June through August (fig. 8). Dry w ights continue increasing into September, but f sh weights do not, due to decreasing moisture con- t ts. Acorn moisture content begins to decrease in l e August, then rapidly drops throughout Septem- b to about 40 percent in October. During the rapid d line in moisture, pericarp color changes from green t dark brown or black. The loss of green color has b n related to decreasing total chlorophyll content (anche and others 1980).

ats and carbohydrates, the major stored energy r erves in acorns, begin to accumulate rapidly in A gust. Crude fat levels in water oak acorns reached 2 percent of acorn dry weight at maturity in late O ober (Bonner 1974a). In this time, cotyledons are n rly filled with coalesced lipid droplets, but they are seldom seen in the embryo axis (Vozzo and Young 1975). Phospholipids are localized in epidermal cells of the apical meristems and the cotyledons. Areas near nucleoli and leaf primordial zones also stain positive for phospholipids.

Soluble carbohydrates gradually increase from July to early September, then drop sharply as they are apparently converted to insoluble forms. At maturity the total carbohydrate content of water oak acorns is 26 percent, with all but 5 percent in insoluble forms (fig. 9) (Bonner 1974b). These insoluble carbohydrates, primarily starches, are much more prevalent in the shoot apex than in the root apex (Vozzo and Young 1975).

Nitrogen fractions and phosphorus, calcium, and magnesium concentrations all decline slowly during the growth and maturation periods of July to November. Although histochemical studies showed heavy staining for protein in the vascular strands leading from the cotyledons to the embryo, protein content as a percentage of acorn dry weight is low (table 1).

Little information exists on the status of growth regulators in developing acorns. Blanche (1981) found that, during maturation of water oak acorns from June to September, free abscisic acid (ABA) and indole-acetic acid (IAA) in the cotyledons increased. Both substances decreased sharply from early October to full maturity in November. Michalski (1970) reported stable levels of auxin in *Q. robur* (English oak) acorns early in maturation, then sharp decreases very similar to those noted in water oak by Blanche.

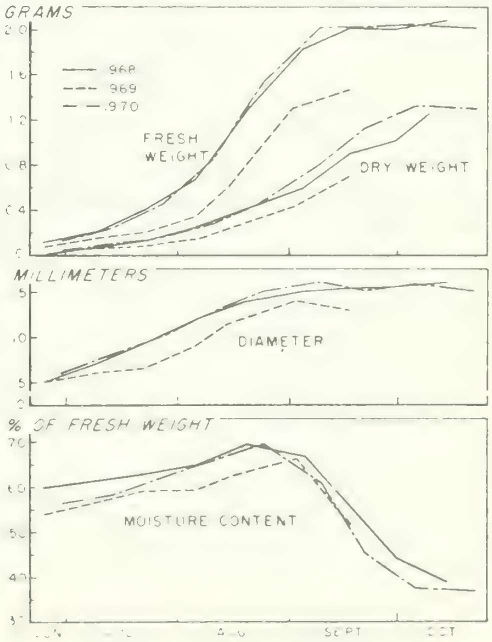


Figure 8.—*Seasonal changes in fresh weight, dry weight, diameter, and moisture content of water oak acorns. (Bonner 1974b).*

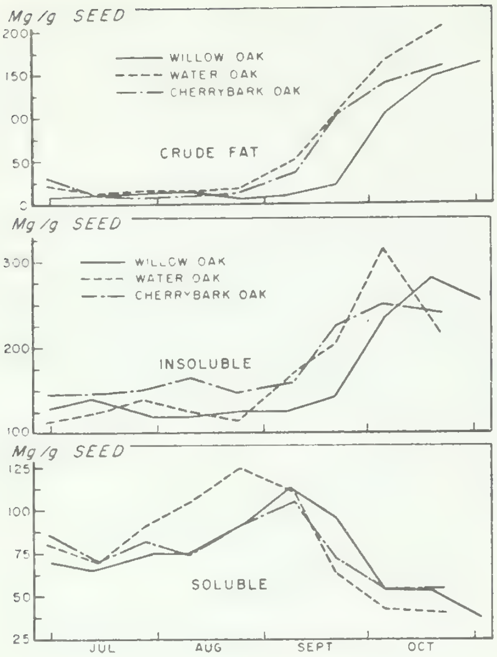


Figure 9.—*Seasonal changes in crude fat and soluble and insoluble carbohydrates in acorns of three red oaks. (Adapted from Bonner 1974b).*

Cytokinin activity decreased from a high init level to a barely detectable level halfway through t maturity period (September), when increases in aco diameter and length became minimal (Blanche 198 Similar trends have been reported for cytokinins in *robur* (Michalski 1974). Blanche (1981) also found i hibitory substances in aqueous extracts of perica tissue, which increased along with acorn develc ment. The inhibitory substances' presence was al confirmed in pericarps of mature water oak acor (Peterson 1983). These trends in growth regulators patterns reported for other seeds, and no unique fur tion with acorn germination can be postulated.

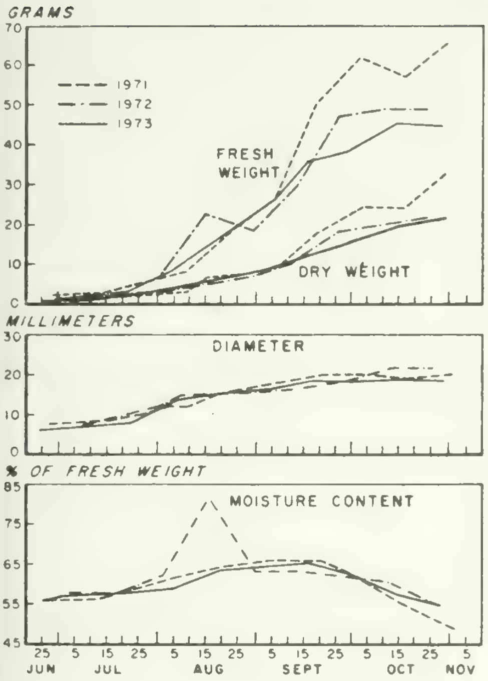
White Oak.—Physical developmental patterns f white oak acorns near Starkville were very similar those of red oak species. The only significant diffe ence was moisture content at maturity. The 50 to percent of fresh weight was some 10 to 15 perce greater than water oak (fig. 10). As white oak aco moisture levels dropped, pericarp color changed fro green to yellow to brown. Some acorns abscissed wi a mottled green and yellow color pattern.

Carbohydrates, comprising 46 percent of acorn d weight at maturity (table 1), are the predomina stored energy reserves in white oak acorns. Season

Table 1.—*Chemical contents of whole acorns of some southern oaks*[1]

Species	Crude fat	Total carbohydrates	Total protein	P	Ca	Mg
	Percent					
Red oaks, *Erythrobalanus*						
Q. cocinea, scarlet	14.6	35.6	4.2	0.07	0.18	0.07
Q. falcata var. *falcata*, southern red	17.0	23.0	5.1	.08	.32	.14
Q. falcata var. *pagodaefolia*, cherrybark	15.8	29.5	4.0	.06	.27	.06
Q. nigra, water	20.3	25.8	3.8	.06	.32	.07
Q. nuttallii, Nuttall	13.2	46.2	4.5	.09	.04	.06
Q. palustris, pin	15.4	45.4	3.8	.08	.04	.06
Q. phellos, willow	19.6	31.2	5.9	.08	.18	.06
Q. shumardii, Shumard	9.8	29.3	3.8	.06	.27	.06
White oaks, *Lepidobalanus*						
Q. alba, white	2.9	46.6	4.6	.08	.22	.05
Q. durandii, Durand	3.8	44.9	6.2	.09	.22	.08
Q. lyrata, overcup	0.9	49.8	4.6	.12	.16	.08
Q. macrocarpa, bur	4.8	45.9	4.3	.10	.08	.06
Q. michauxii, swamp chestnut	3.3	56.1	4.1	.12	.08	.06
Q. muhlenbergii, chinkapin	6.6	34.5	4.4	.08	.18	.08
Q. stellata, post	5.2	37.9	3.8	.08	.25	.06
Q. virginiana, live	8.2	46.4	4.4	.06	.06	.07

[1] Data from Bonner (1971, 1974a).



igre 10.—*Seasonal changes in fresh weight, dry weight, diameter, and moisture content of white oak acorns. (Bonner 1976b).*

aerns during maturation were not too different rch those of water oak. Soluble carbohydrates slowly eined until mid-July, peaked slightly in August, nh dropped rapidly as they were converted to insolb forms. Carbohydrates are prominant in the periap and root apex tissue as well as in cotyledon tissue Vzzo 1978).

rude fat levels reached only about 4 percent in whte oak at maturity, making it a very minor compoet of stored acorn reserves in this subgenus. Phoshipids are concentrated in the cotyledons, embryo x, and shoot apex. All cells with phospholipids have are dense droplets in groups of two or three, which lost fill each cell (Vozzo 1978).

s in water oak, total protein content is not high in whe oak on a dry weight basis (table 1). Cytoplasmic orents in the epidermis and its adjacent lower layrshave the greatest staining for proteins in cotyleor. Although there is little evidence of protein elsewhre, there are large unidentified protein storage oces stained by chloramine-T in some cotyledon el. However, when stained with ninhydrin, they es protein negative. Embryo axis and root apex also hc the presence of protein in mature, ungerminated cons (Vozzo 1978).

Ivels of other chemical components of white oak cons are shown in table 1.

tcage

Vry little research has been conducted on nebolism of acorns during storage. Due to the naturally high moisture levels of acorns, metabolism during storage is similar to that demonstrated during stratification. During 8 months of storage at 2°C, acorns of water, Shumard, and cherrybark oaks demonstrated decreasing lipid levels and slowly increasing soluble carbohydrate levels (Clatterbuck and Bonner 1985). Insoluble carbohydrate levels increased for 3 or 4 months, then decreased. This reversal coincided with radicle emergence in the storage containers.

Respiration data in this study (Clatterbuck and Bonner 1985) indicated lipid respiration at first (RQ's 0.65-0.75) and then increasing metabolism of carbohydrates. Levels of CO_2 will increase to around 10 percent in closed storage of red oak acorns (Vozzo 1976; Tylkowski 1976). The best acorn quality was maintained at these high CO_2 levels, but no cause and effect relationship has been demonstrated. Less oxygen is consumed under these conditions (Vozzo 1986), and this may be a simple explanation of the CO_2 situation.

Similar trends in metabolism of stored reserves were found in white oak acorns (Clatterbuck and Bonner 1955), but lipid levels were much lower than in the red oaks. In storage tests of *Q. robur*, Tylkowski (1977) also reported more effective storage at high CO_2 levels than at low ones.

Germination

Water Oak.—Acorns of the subgenus *Erythrobalanus* usually exhibit delayed germination, commonly described as dormancy. As dormancy is overcome by stratification or other methods, metabolic activity increases within the acorns (Vozzo and Young 1975).

During stratification, starch is translocated from the shoot to the root of the embryo. After germination, however, starches are evenly distributed between shoot and root. Cotyledons show a continuing loss of starches during the entire process of germination. Similarly, hemicellulose is rapidly assimilated by cotyledons during germination, and its levels decrease quickly from dormant to germinated embryos.

Lipids are translocated from cotyledons to embryo axes as acorns proceed from dormancy to germination. During stratification, these droplets separate and are more commonly found as single drops in small groups in germinated embryos.

The respiratory quotient (RQ) increases as acorns pass from the dormant state (0.3) through stratification to germination (0.7). This trend indicates an increase in carbon dioxide evolution from stratified embryos. It also suggests that less carbohydrate and more lipid substrates are being used. During germination, protein location in embryos changes. Meristems in germinated embryos stain heavily near the root apex. The connecting cotyledon strands remain heavily stained for proteins even though the cotyledons begin to disintegrate.

Embryos from stratified acorns generally stain positive for proteins in the embryo axis, whereas dormant embryos are unstained. Villiers (1972) pointed out that RNA must be abundant during protein synthesis in dormant seeds. Heavy concentrations of proteins in these embryos' meristems probably indicates the abundant protein synthesis necessary for subsequent germination.

Nucleic acids are concentrated in apical stem meristems in all embryos observed. In dormant embryos, nucleic acids are diffused and extend from the shoot apex into cotyledons. In stratification, the concentration of nucleic acids increases, primarily in stem apices. Epidermis also stains positive for nucleic acids. In germinated embryos, the root apex is completely stained for localization of nucleic acids. For water oak embryos, DNA content and localization increase as germination proceeds. Although no direct relation is reported between distribution of protein and nucleic acids, similarities exist for each treatment stage: dormant, stratified, and germinating.

Water oak embryos, then, may be described as having diminished carbohydrate and lipid localization as the embryo passes through stratification to germination. Both substances are translocated from the cotyledons, and along with proteins, are moved towards the root apex as germination proceeds.

Although some red oak acorns collected in late September near Starkville germinated normally, the best germination was always obtained from acorns collected in late October and early November. These collections were made when moisture contents had fallen to 40 percent or below (fig. 8), and storage food concentrations were at peak levels for crude fat (20 percent) and total carbohydrate (26 percent) (fig. 9).

White Oak.—Since these acorns do not normally exhibit dormancy, there is no dormant condition to analyze. In fact, viviparity is common in several white oaks (*Q. virginiana*, *Q. alba*) in the Deep South, when rainy weather occurs during acorn maturation. White oaks do not store well at all, and they germinate readily at low storage temperatures (1°–3°C).

Generally there is little difference in the localization patterns of insoluble carbohydrates for either ungerminated or germinated acorns. In both conditions, the starch grains in embryos are similar in size, number, and stain intensity. However, starch grains in cotyledons of ungerminated acorns differ from those in germinated ones by having a few small starch grains one layer beneath the epidermis and by having abundant and large grains in the deeper cell layers. This pattern is reversed in germinated acorns. Undifferentiated cells of germinated acorns stain more heavily than do those of ungerminated ones in both embryonic and cotyledon cells. This pattern is also observed in the leaf primordia of germinated acorns, though the staining is less dense.

The pericarp in both conditions also shows positive histochemical staining for lignin. An interesting observation in both germinated and ungerminated embryos is that damaged tissue displays a stain reaction for lignin whereas healthy tissues do not, a development particularly manifested by phloroglucinol treatments. In one ungerminated embryo cotyledon section, cells stained heavily for lignin in an injured area. When the same cells of the surrounding damaged area were tested for starch (IKI + PAS), an intense starch concentration was observed. Individual cells that stain positive for lignin contained few starch grains, although starch grains are plentiful in the immediate area.

For germinated embryos, phospholipids are concentrated in the shoot apex and are seldom seen in cotyledons.

Nucleic acids in both ungerminated and germinated embryos are concentrated in meristems and vascular traces connecting the embryo axis to the cotyledons, and in the root cap. The localization pattern does not appear to change during germination.

Germination tests indicated that physiological maturity for acorns of white oak occurred by late October and early November in Starkville, just as for the red oaks. Maturity coincided with total carbohydrate contents of 46 percent and moisture levels of 50 to 55 percent.

General Considerations

The magnitude of change in chemical fractions is dominated by the large amount of storage tissue in the cotyledons of acorns. The cotyledons comprise 99 percent of total acorn dry weight at maturity (Vozzo 1973). Changes in nitrogen and phosphorus compounds in the meristematic regions obviously are occurring during maturation, but the macro-analyses used in our studies on total acorn tissue did not detect these changes. Comparable chemical analyses for southern oaks are summarized in table 1.

While acorns of many oak species sprout easily without stratification, white oak acorns will germinate prematurely during storage much more readily than water oak acorns. This behavior might be explained by differences in the localization of biochemical components during germination. Like *Triticum* (Evans and Berg 1971, 1972) and *Brachychiton* (West and Gunckel 1968), water oak shows a gradual movement of carbohydrate reserves from the cotyledon to the root apex of the embryo, as well as a shift in phospholipids during germination (Vozzo and Young 1975). White oak acorns, however, store carbohydrate reserves in the embryo axis prior to germination. During the germination process the acorns also utilize phospholipid reserves, since lipid concentrations subsequently shift from the cotyledons to the embryo axis (Vozzo 1978).

The progressive shift of white oak protein reserves from cotyledons to shoot and root apices during germination agrees with reports for other species, in which protein mobilization is apparently activated in the cotyledon cells by the accumulation of the enzyme endopeptidase (Harris and others 1975). White oak and water oak apparently do not differ in their utilization of nucleic acids. The localization patterns for embryonic nucleic acids of both species are similar to those reported for *Ricinus* (Sturani 1968); staining patterns for both nucleic acids and proteins agree with the results obtained for *Arachis* cotyledons and *Triticum* embryos (Marcus and Feeley 1964, 1965; Villiers 1972).

The localization patterns and distributions mentioned here are recognized as occurring with germination, but they do not necessarily trigger it. The results do indicate the nature of the changes that reserve metabolites, particularly carbohydrates, exhibit in the embryonic axis as a function of germination.

DORMANCY

As mentioned earlier, acorns of the subgenus *Lepidobalanus* (white oaks) do not have complete dormancy, at least in the South. There is epicotyl dormancy in some white oak species, notably white, chestnut, and overcup (Farmer 1977; Bonner, unpublished data). Red and black oaks (subgenus *Erythrobalanus*) exhibit variable dormancy. Not only do species differ in dormancy, but within a species differences can be due to geography or altitude. Farmer (1974), for instance, found that chilling requirement for germination of northern red oak increased with latitude and altitude of seed source.

Although seed dormancy is a natural protection for species regeneration, it must be understood and controlled for practical silvicultural management. The natural mechanism for breaking dormancy is simply the cold, wet environment in which acorns overwinter in litter on the forest floor. In forestry, we duplicate these conditions by storing fully-imbibed acorns at temperatures just above freezing for long periods of time. The reasons this treatment (stratification) overcomes dormancy are not completely clear.

A prominent contemporary concept of seed dormancy involves the interaction of plant growth regulators. These regulators may be either inhibitors or promotors and act together to influence the net result of germination or dormancy (Amen 1968). Nikolaeva (168) has found that two plant growth regulators in particular act together: indoleacetic acid (IAA) and abcisic acid (ABA). Quantitative and qualitative analyses have been made for IAA, ABA, gibberellic acid (GA), and cytokinin in embryos of maturing and stratified water oak acorns (Blanche 1981; Hopper and Vozzo 1982). Results of both studies indicated that IAA and ABA levels increase with acorn development but decrease with acorn maturity. IAA content is always greater in the cotyledon than in the pericarp, while ABA is equally distributed between the two. Conversely, cytokinin activity decreases during maturation. Blanche (1981) found that the cytokinin activity pattern was consistent with the high rate of cell division taking place during maturation. During stratification, IAA decreased from day 10 to day 50. The inhibitor-promoter balance in the embryo axis changed between day 30 and day 50, as ABA increased and GA increased (Hopper and Vozzo 1982).

Further support for the inhibitor-promoter concept may be the reported stimulation to germinate dormant acorns by treatment with exogenous GA. Vogt (1970) and Farmer (1974) reported GA-stimulated germination of northern red oak; we have had similar results for cherrybark oak (*Q. falcata*, var. *pagodaefolia*) (Bonner 1976b).

Dormancy in *Q. rubra* has also been attributed to the pericarp by Jones and Brown (1966). They induced germination by removing or clipping the pericarp and concluded that dormancy was the result of inhibited cell expansion. Hopper and others (1985) also concluded that the pericarp was significantly involved in dormancy of *Q. rubra*, and Bonner (1968) found pericarps to inhibit germination of four red oak species. Pericarp removal from acorns had no significant effect on seedling growth of water oak, but it increased acorn germination from 10 to 55 percent (Hopper 1982).

Peterson's (1983) results with water oak showed that, although pericarp or seed coat tissues were not impediments to water uptake, the pericarp might entrap gases which could then affect water uptake. With normal water imbibition, the pericarp did expand with swelling cotyledons. After stratification at 5°C for 4 to 7 weeks and incubation at 20°/30°C, the pericarp split and radicles emerged. Mechanical strength of pericarps did not change during stratification. Peterson also found chemical inhibitors in the pericarp tissues.

Another possible factor in acorn dormancy is the interaction of seed coat (pericarp) and microorganisms. Microorganisms have been isolated in mixed culture from water oak acorns (Vozzo 1984). The conditions used for acorn stratification are also favorable for the growth of these isolated organisms—*viz*. damp, dark, chilly, and aerobic conditions. It may be more than coincidental that the duration and the growth conditions of acorns are optimal for the microorganisms as well as for the stratification process. Pre-germination treatment for water oak acorns may amount to creating conditions that allow seed coat organisms to incubate and grow over the surface while exuding sufficient enzyme activity to erode the surface layer. This action could expose the ends of translocation channels and loosen the pericarp matrix to increase water and gas passage.

The most definitive studies on acorn dormancy are those of Peterson (1983) on water oak. He concluded that delayed germination (dormancy) was the result of at least three factors: (1) Mechanical strength of the pericarp; (2) chemical inhibition by the pericarp, which was alleviated by stratification for approximately 4 weeks; and (3) slow increase in capacity to imbibe the water required for pericarp rupture. This last factor apparently did not depend on temperature within the range of 5° to 30°C, and operated during the entire stratification and germination period. Although other factors may be involved, the Peterson model of dormancy seems to explain germination behavior reported for other southern red oaks.

PREDATORS

Microorganisms.—Although the genus *Quercus* has been thoroughly studied regarding pathological problems (Hepting 1971), few references pertain to acorn pathology. Both *Q. agrifolia* and *Q. wislizenii* are subject to oak drippy-nut disease (Hildebrand and Schroth 1967). After acorn puncture by wasps, a plant exudate appears and drips. The causative organism is *Erwinia quercina*. In France, the most significant fungus for acorn infection is *Ciboria batschiana*, which causes black rot of acorns of *Q. robur* and *Q. petraea* (Dealtour and Morelet 1979).

The primary concern for acorn pathology is related to seed storage. Vozzo (1984) reported fungal observations isolated from both *Q. alba* and *Q. nigra* acorns. Axenic sub-cultures produced pure culture determinations for *Epicoccum purpurascens* and *Fusarium solani*. Although these isolations were believed to be from acorn surface contaminants, it must be noted that cracks were present in the acorn pericarps. These cracks may have allowed internal cotyledon contaminants to grow on the agar growth medium. However, cracks are quite common in both freshly collected as well as stored acorns. If certain contaminants are specific for the pericarp surface, as opposed to the cotyledon-embryo tissues, they would have potential infection capability through these commonly occurring, natural fissures in the pericarp.

One other consideration is the possibility of symbiotic or even beneficial associations between seed germination and seed contamination. Such associations have been reported for mountain rice (Probert 1981) and orchids (Rayner 1915). In the latter case, *Calluna* seeds were infected during embryogeny from the mother plant, resulting in endotrophic mycorrhizae in the subsequent seedling. The possibility of beneficial fungal associations with acorns should be considered along with possibilities previously mentioned regarding how stratification may overcome dormancy.

Insects.—*Curculio* species are major pests in *Quercus* seeds (Baker 1972; Gibson 1972; Gibson 1982). They infiltrate oak acorns by depositing eggs in chambers, and larvae can be observed feeding on cotyledon tissue at the time of acorn collection in late summer and early autumn. Since infested acorns are routinely discarded, the adults of *Curculio* are seldom seen by seedsmen. According to Baker (1972), acorns are infested by *C. sulcatulus*, *C. pardalis*, *C. orthorhynchus*, *C. longidens*, and *C. humeralis*. *Curculio* sp. were found in acorns of white oak, water oak, willow oak (*Q. phellos*), and southern red oak (*Q. falcata*) in Starkville collections, but species identifications were not made (Vozzo 1984). Gibson (1972) reported that white oak damage is caused by seven *Curculio* species. Northern red oak acorns are commonly infested by five *Curculio* species (Gibson 1982).

Melissopus latifferanus (filbertworm) is reported to feed on acorns and is responsible for severe destruction to acorn crops, particularly during poor crop years (Baker 1972; Gibson 1972). It has been observed in both southern red and water oaks at Starkville (Vozzo 1984).

The warehouse moth, *Ephestia*, a common pest of stored seed and grain, is not usually found in the wild. Considered a secondary infestation during storage, the moth was found only on water oak at Starkville (Vozzo 1984).

Valentinia species commonly feed on acorns, nuts, cones, and seeds. The larvae attack seed and prey on other insects associated with the host plant. The acorn moth, *V. glandulella*, is reported to infest acorns in the Southern United States (Baker 1972). Vozzo (1984) found this species on four oaks at Starkville, and Gibson (1982) reported it as a pest of northern red oak.

Other known insect predators for white oak are *Conotrachelus* weevils, and two gall wasps, *Cynips glandulosus* and *Callirhytis* spp. (Gibson 1972). Additional species which attack northern red oak include *Callirhytis fructosa* and three *Conotrachelus* species (Gibson 1982).

Vozzo (1984) studied the common infestation of insects and fungi in acorns of four species. Fungal isolates were recovered from the head, gut, and carcass of *Curculio* larvae. A *Penicillium* sp. was isolated from head and carcass portions, while an undetermined white fungus with sterile mycelia was isolated from the head, gut, carcass, and the whole larvae. Only two unidentified fungal spores were observed from sectioned gut of *Curculio* sp.

The scarcity of fungal spores found in insect parts isolated from acorns would not indicate that the insect is a vector or source of fungal contamination to the acorn. Limited observation, however, does not firmly establish a theory. Similarly, another question arises from the study. Did the few spores present in *Curculio* gut result from insect transmission to the acorn, or was the gut infested as a result of fungal contamination of the seed surface? Perhaps the acorn is a vector contaminate its associated insect population, which n turn is a secondary carrier to other organisms. eed for additional study is indicated.

Part II. Handling and Management of Acorns

COLLECTION

Acorns should be collected as soon as they are physiologically mature. In the Midsouth this condition occurs in late October to early November. Some year-to-year variation in ripening date occurs for individual trees, but this difference rarely exceeds 2 weeks. Variation in acorn ripeness is also found within a single crown. Acorns on lower branches usually ripen before those in the upper crown.

Large collections of acorn crops require careful planning. If the seed crop is very light, it may be best to postpone collection until next year. Acorn quality is frequently poor in light crop years. Also, infestation by *Curculio* sp. and other insect predators occurs in a very high proportion of the total acorns in a light crop year. When a large acorn crop is indicated, collection efforts should be intensified.

Maturity Indices

Although chemical indices of maturity are available for some species (see Part I), their use is impractical. Visual and physical characteristics of the acorns furnish simple, dependable maturity indices. Among the red oaks, the following are characteristics of a mature acorn:

1. The pericarp has lost its green color and is primarily dark brown or black.
2. The pericarp easily slips from the cup without being forced or without leaving pieces of the cup still attached to the pericarp.
3. The cup scar is "bright" in appearance. In southern red and cherrybark oaks, the cup scar may be a bright pink or orange in color. Yellow or orange is common in some other species of red oaks.
4. A cross-section of the acorn will show the following colors: high-fat species (water, willow, cherrybark)—dark yellow to orange; low-fat species (Shumard)—light yellow.

Among the white oaks, the following characteristics indicate maturity:

1. For most species, the pericarp has lost its green color and is primarily brown or black. White oak and swamp chestnut oak are sometime exceptions to this rule, since acorns from many trees are fully mature when still yellow or even a mottled yellow and green.
2. Acorns slip easily from the cups as in the red oak group. Overcup oak is an exception to this rule because its acorns retain their cups when they fall.
3. Acorn cross-sections will show the cotyledon to be firm and white to yellow in color.

Methods of Collection

The quickest and cheapest way to gather large quantities of acorns is to collect from the tops of trees felled in logging operations. When acorns are fully mature at the time of felling, they usually fall from the cups when the top hits the ground. Collectors can pull away the branches and easily pick the acorns from the ground. If acorns are not quite mature (or if the tree falls slowly), they may remain in their cups for easy picking by collectors standing on the ground.

Some ripening of immature acorns may occur while they are still attached to the logging tops. If the atmosphere is humid and the felled tops dry slowly, as many as 5 to 7 days may pass before the foliage is desiccated. When the foliage becomes fully desiccated, ripening apparently stops.

Immature acorns, unlike the seeds of some hardwood species such as sweetgum and yellow-poplar, cannot be ripened artificially after picking (Bonner 1979). Detached acorns have no external source of nutrients as the seeds of the other species have in their fruit tissues.

From standing trees, acorns can be collected by sweeping them up after they fall on the ground or by spreading dropcloths under the trees. A major caution in these two methods is to ignore the first acorns to fall; they are usually damaged by insects or birds. Although seldom, if ever, used on oaks in this country, tree shakers can easily dislodge mature acorns (Stein and others 1974).

CLEANING AND CONDITIONING

At maturity, red oak acorns contain about 40 percent moisture and white oak acorns about 50 percent (Bonner 1974b, 1976b). It is very important that excessive drying be prevented! A loss of 5-percent moisture can be tolerated, but further drying will lower acorn quality. Viability will be completely lost when moisture content drops to about 25 percent and remains there. Laboratory tests have indicated that water oak acorns will survive temporary desiccation in the 15- to 18-percent moisture range if they are rehydrated quickly (Agmata and Bonner 1985). In collection operations, however, the key to obtaining acorns of high quality is to avoid any desiccation.

On the collection day, acorns should be floated in water to remove leaves, acorn cups, insect-damaged acorns, and other trash. This step also is a major aid in maintaining desirable acorn moisture levels. Sound, healthy acorns should sink in water. If conditions are extremely dry at collection, the acorns should be left in water 16 to 24 hours to raise moisture contents. This is critical for acorns collected from the ground because many sound acorns will float at first. Acorns collected during wet, rainy weather are usually moist enough to permit good cleaning separation without a soak period. With large batches (a bushel and larger), some stirring action is needed to give all acorns a chance to float.

After flotation, the trash should be skimmed off and the water drained away. Acorns should then be placed in cold storage, even if they are to be planted in a few days. Surface drying before storage is not necessary as long as there is not enough water present to form a pool at the bottom of the container.

Although seldom practiced, sizing of acorn lots is possible by screening or by running them over gravity separators. Round-hole screens are available for air-screen seed cleaning machines that will size the smaller acorns, such as water, willow, or cherrybark oaks. Sizing with gravity separators is not very efficient; screens should be used where sizing is desired.

The possible advantages of sizing acorns for planting has not been investigated fully. Farmer (1980) found that initial leaf areas of seedlings of northern red, chestnut, white, and bear oaks were positively correlated with acorn size. Kleinschmit and Svalba (1979) reported a strong positive correlation between acorn weight and height growth at 3 years for *Q. robur* and *Q. petraea* in Germany.

TREATMENT FOR INSECTS

When acorn collections are found to contain numerous weevil larvae, the tendency is to want to kill the insects to prevent further damage. Two methods for killing larvae (Olson 1974) present great risks for the acorns. The most common method is to immerse the acorns in hot water (120°F) for 40 minutes. Temperatures above 120°F, however, may kill the acorns. The second, and less desirable method, is to fumigate the acorns with methyl bromide, carbon disulfide, or thiamine bisulfate. Because of the acorns' high moisture contents, chemical fumigation may also harm the acorns if the treatment is not done properly.

Avoiding all treatment of acorns is the safest alternative! If proper flotation has been used to clean the seed lots, most infested acorns will have been removed. The larvae do not attack intact acorns during storage, so infestation cannot increase. Most larvae will emerge from the acorns during cold storage and die in the bottom of the container. In this way some infested acorns may be salvaged, because the larval feeding must destroy the embryo axis to prevent germination. Much feeding is found in the cotyledon tissues only, but partial damage there will not necessarily prevent germination and normal growth. Larva emergence can be further encouraged by moving th acorns back and forth from cold (2°–5°C) to room temperature several times.

STORAGE

Seeds that cannot be stored by orthodox means (lo moisture content, sub-freezing temperatures) ar often called recalcitrant. Seed storage of this group which includes all species of *Quercus*, is still th greatest challenge in seed technology. Acorns of th red oak subgenus can be stored for 3 to 5 years unde special conditions, but quality decreases each year Acorns of the southern white oaks cannot be successfully stored longer than over winter, with the curiou exception of overcup oak.

Red Oak Group.—For red oaks, the best storag method is one that maintains acorn moisture conten above 30 percent, allows some gas exchange with th atmosphere, and keeps the temperature near bu above freezing (1° to 3°C). Under these condition southern species—such as water, Nuttall, and cherrybark oaks—will maintain good viability (60 percen or more) for at least 3 years (Bonner 1973). Very similar methods have proven successful for northern re oak and scarlet oak (Farmer 1975; Suszka an Tylkowski 1982). Shumard and willow oak acorns d not seem to store as well.

When the moisture content of stored acorns is 3 percent or more, respiration in them is quite activ This condition creates a continual, but slow, decreas in acorn dry weight and a corresponding slow increas in moisture content, expressed as a percentage acorn fresh weight. The cherrybark oak data in tabl 2 illustrate the gradual upward trend of acorn moi ture during storage. For this reason, true equilibriu between internal acorn moisture and the storage a mosphere is never reached. However, approximat equilibrium moisture contents (%) have been dete mined for a few species (Bonner 1981), as follows:

	Storage Conditions	
	40%–55% RH, 4°–5°C	95% RH, 4°–5°C
Shumard oak	13	32
Water oak	17	29
White oak	37	50

Because starch is more hygroscopic than fa starchy acorns (white oaks) absorb more moistu than fatty acorns (red oaks). This explains the high moisture contents of the white oak acorns under th same conditions.

Table 2.—*Germination and moisture contents of cherrybark oak acorns stored in polyethylene bags at 3° and 8°C*[1]

Original moisture content and storage period	Germination		Final moisture content	
	3°C	8°C	3°C	8°C
	Percent			
24 percent moisture				
6 mo	80	76	27	28
18 mo	9	0	30	34
30 mo	25	24	32	33
31 percent moisture				
6 mo	99	99	34	34
18 mo	99	96	35	35
30 mo	81	71	36	36
33 percent moisture				
6 mo	100	98	34	32
18 mo	93	95	31	36
30 mo	94	34	37	40

[1] Bonner (1973).

Because of the high rate of respiration, some gas exchange with the atmosphere must be allowed. Numerous tests have shown that air-tight storage containers are lethal to acorns. Polyethylene bags with a wall thickness of 4 to 10 mils are good containers for red oaks. The material is permeable to carbon dioxide and oxygen, yet largely impermeable to moisture. Thinner polyethylene is highly permeable to moisture vapor, and acorns stored in it will dry excessively in low-humidity conditions. Polyethylene thicker than 10 mils restricts gas exchange too much. There is an apparent natural increase of CO_2 in storage containers, and better viability retention has been reported in CO_2-enriched storage atmospheres (Vozzo 1976; Tylkowski 1976). The most common practice is to store acorns in drums, cans, or boxes having a polyethylene liner bag. In this type of storage the container top should never be completely closed. Additional aeration is sometimes supplied by the weevil larvae which emerge from acorns and eat through the bottom of the polyethlyene bags.

Successful storage of northern red oak acorns for two winters in Poland has been accomplished by mixing the acorns with dry peat or pine sawdust (1:1 by volume) and storing them at −1° to −3°C in metal milk cans with tops unfastened (Suszka and Tylkowski 1982). Some acorns retained viability for five winters, but storage for more than two was not recommended. The peat or sawdust prevents desiccation. Another possible advantage of this method is that it separates all acorns within the peat and sawdust and thus avoids the spread of pathogenic fungi. This method has been tested on water and cherrybark oak acorns in our laboratory, but neither peat, sawdust, nor dry sand were as good as 4-mil polyethylene bags without media.

In Europe, acorns of *Q. sessiflora* and *Q. pendunculata* are often stored over one winter in pits 60 to 100 cm deep, with the top 20 cm being filled with straw or litter (Walkenhorst 1985). When radicles start emerging, the acorns are removed and sown. This system might work in the Northern United States, but mild winter temperatures in the South could prevent its use there.

Johnson (1979) reported successful 6-month storage of Nuttall oak acorns in drums of water maintained at 2° to 5°C. Tests at our laboratory gave similar results for water and cherrybark oak acorns for 5 months, but longer storage by this method (17 and 29 months) was not nearly as successful as storage in 4-mil polyethylene bags. For 5 to 6 months of storage over winter, however, this water method is satisfactory. One good feature of this method is absolute hydration of the acorns for the length of the storage period.

Another problem in acorn storage has been the tendency of acorns to germinate in the storage container. The epicotyls usually do not emerge at 2° to 5° C, but the radicles appear readily. This condition, commonly called pre-sprouting, can produce etiolated radicles 6 to 8 inches long, which are easily broken by any movement, especially planting (fig. 11). Even if the radicles are not broken, many succumb to microorganism attack during storage. We have tested a large group of chemical inhibitors to prevent pre-sprouting in storage, but no successful treatment has ever been found.

The best solution to pre-sprouting, as with weevil larvae, may be to ignore the problem. Where radicle tips have been broken in planting or killed by microorganisms, secondary root development often ensures seedling survival and even produces a multiple-root seedling which may survive outplanting better than a seedling with only one carrot-like root. A study

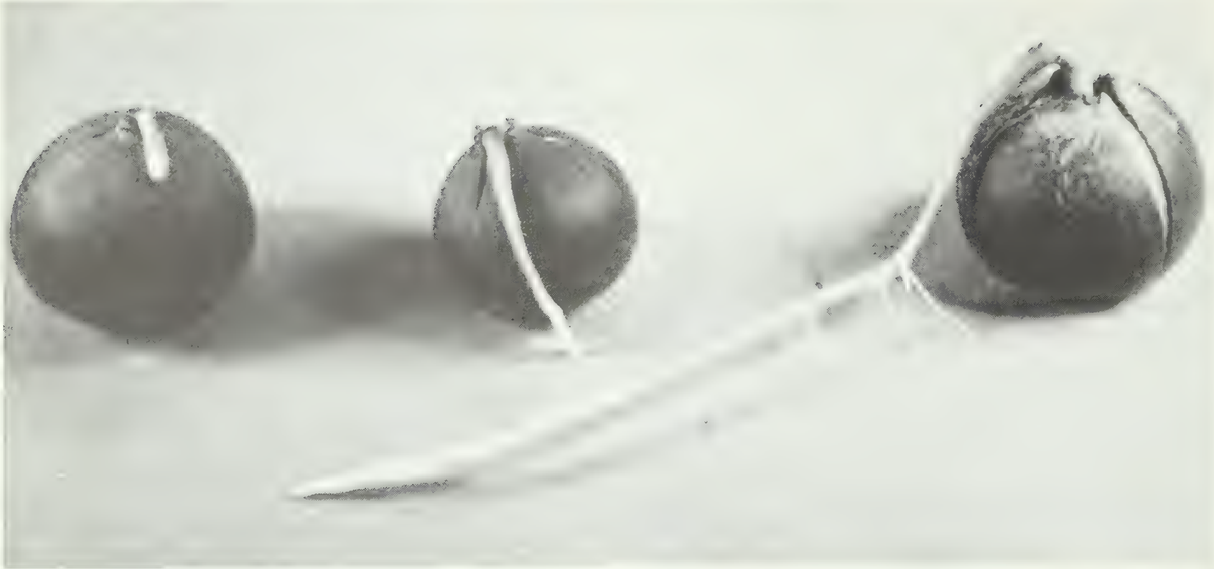


Figure 11.—*Water oak acorns that sprouted during storage at 2°C.*

with cherrybark and Shumard oaks showed that broken radicles did not adversely affect seedling production at all for these species (Bonner 1982).

Red oak species vary in degree of dormancy. Water oak is one of the most dormant, and its acorns usually germinate very little in storage. Other species, such as cherrybark or Shumard, are not very dormant, andthey exhibit excessive pre-sprouting. The relationship between dormancy and storability suggests that the more dormant species maintain viability better during storage than the less dormant species.

White Oak Group.—With only rare exceptions, acorns of the white oak group cannot be successfully stored more than 4 to 6 months (over winter). These non-dormant species sprout very readily in storage and die rapidly. The best recommendation for white oaks is to store them in the ground by planting in the fall.

If white oaks are held over winter for spring planting, the best conditions are almost the same as those recommended for red oaks: temperatures just above freezing (2°–3°C), maximum acorn moisture content (45 to 50 percent), and containers that allow gas exchange. There is good evidence, however, that cloth bags or a thinner polyethylene (1.75 mil) are better for white oak, because of the need for greater aeration (Rink and Williams 1984). The preceding recommendations for flotation, sizing, and ignoring the weevil larvae apply to white oaks.

A few exceptions to non-storability of white oak acorns are documented. Suszka and Tylkowski (1980) have demonstrated successful storage of English oak (*Q. robur*) acorns over three winters by mixing them in sawdust or peat at −1°C, as described previously for northern red oak. Storage tests with southern white oaks in our laboratory have been largely unsuccessful. The single exception has been one lot of ove cup oak which retained excellent viability for 1 ye (table 3). Since overcup is one species that retains i wrap-around cup when disseminated, one could spe ulate that the cup retards oxygen uptake by t acorns, thus slowing metabolism and prolonging v ability. One lot of live oak (*Q. virginiana*) also germ nated 60.7 percent after 1 year and 17.6 percent aft 2 years.

Table 3.—*Viability retention of various southern white oak speci stored at 2°C, high moisture content, and in polyethyle bags*

Species	Germination percent Original	6 mo	1 yr	2 y
Q. alba—white	90+	7.0	....	..
Q. virginiana—live	96.0	...	60.7	17
Q. muhlenbergii—chinkapin	91.3	...	39.0	2
Q. michauxii—swamp chestnut	86.1	...	65.1	2
Q. lyrata—overcup	....	...	95.8	..

STRATIFICATION

All acorns of the red oak group exhibit some degr of dormancy, and stratification is commonly used enhance germination rate and uniformity in the nu ery. The common stratification technique is the sa as that for other tree seeds: moist storage at 2° to 5 for several months. Current recommendations length of stratification are summarized in table 4. F

Table 4.—*Recommended stratification lengths for southern red oaks in the Midsouth*[1]

Species	Stratification period
	Weeks
Q. coccinea—scarlet	4–8
Q. falcata var. *falcata*—southern red	4–8
Q. falcata var. *pagodaofolia*—cherrybark	4–6
Q. nigra—water	8–12
Q. nuttallii—Nuttall	4–8
Q. phellos—willow	4–8
Q. rubra—northern red	4–6
Q. shumardii—Shumard	8–12
Q. velutina—black	4–8

[1] Should be fully hydrated at 2°C, with some gas exchange possible.

red oak species not listed in table 4, a general recommendation is 4 to 8 weeks. Local seed sources may do better with longer or shorter periods. In general, northern sources will require longer stratification periods than sources from the southern portion of a species range. Local source tests with varied stratification periods are desirable.

If acorns are fully hydrated in cold storage, then stratification is actually taking place in this manner. In a Tennessee study with northern red oak (Farmer 1974), cold storage was sufficient to break dormancy, and additional stratification was not needed. To ensure dormancy removal, however, acorns to be stratified should be soaked again for 24 hours prior to the start of stratification. The imbibed acorns should be put in polyethylene bags (4-to-10-mil thickness), and the bags should be placed on their sides in a refrigerator at 2° or 3°C. The bags should be turned over each week or two to ensure that water does not continually pool in the bottom of the bags. If excess water is observed, it should be drained from the bags.

In direct seeding operations, better results have generally been obtained with unstratified acorns sown in winter than with stratified acorns sown in the spring (Johnson 1984). Site conditions are extremely important also; excess water on the site may force delays, which dictate the use of stratified acorns. The "stratification effect" from moist storage may be enough to stimulate germination in many cases.

For many years, nurserymen mixed acorns with moist peat or sand during stratification to help maintain seed hydration. This practice does not improve the stratification effect, however, and it results in an extra task of separating acorns from the medium at sowing time.

Many red oaks will begin germinating during the stratification period, as they do in storage. The higher the stratification temperature, the more presprouting will occur. Although this can make sowing more difficult in nurseries, it does not necessarily decrease the chances of a good seedling crop (Bonner 1982). Planting in the fall or winter without stratification is also an alternative for red oaks. Presprouting can be avoided, but uniformity of emergence in the spring will suffer. Direct seeding operations usually employ mechanical planters to put acorns 2 to 4 inches into the ground. Pre-sprouted acorns present problems, because the radicles prevent even flow of acorns through the planter. This situation is another reason why unstratified acorns planted in winter are preferred in direct seedings.

White oak acorns from southern sources are not dormant, and stratification is not normally used with these species. Further, because these acorns store so poorly, fall planting of untreated acorns is usually preferred. More northern sources of some white oaks, however, exhibit a stronger dormancy, and stratification can be beneficial to some.[2]

TESTING

Sampling

Efficient use of acorn supplies will normally require testing to determine seed quality and sometimes moisture content. Proper methods are required so that the samples truly represent the seed lots.

Small acorns can be sampled with large seed triers, but the usual procedure is to thrust the hand into the container and remove handfuls of acorns. The hand should be inserted with the fingers extended together, and closed as it is withdrawn. It is difficult to sample deeper than 40 cm with this method, so containers may have to be partially emptied to facilitate sampling. The total sample should be made up of equal portions taken from evenly distributed volumes of the total seed lot. The sample submitted to the testing facility should contain a minimum of 500 acorns per lot.

Germination Test

The usual method for evaluating seed quality is a laboratory germination test. Evaluation in a testing laboratory is preferred, of course, but rapid losses of acorn quality during shipment of samples is a major problem. If controlled temperature facilities are available, germination can be tested by the "cut and peel" method, which is very similar to techniques used for official tests (AOSA 1978). The procedure is simple:

1. Cut acorns in half (pruning shears are good for this) and discard the half with the cup scar (fig. 12).

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[2] R. Tinus, personal communications.

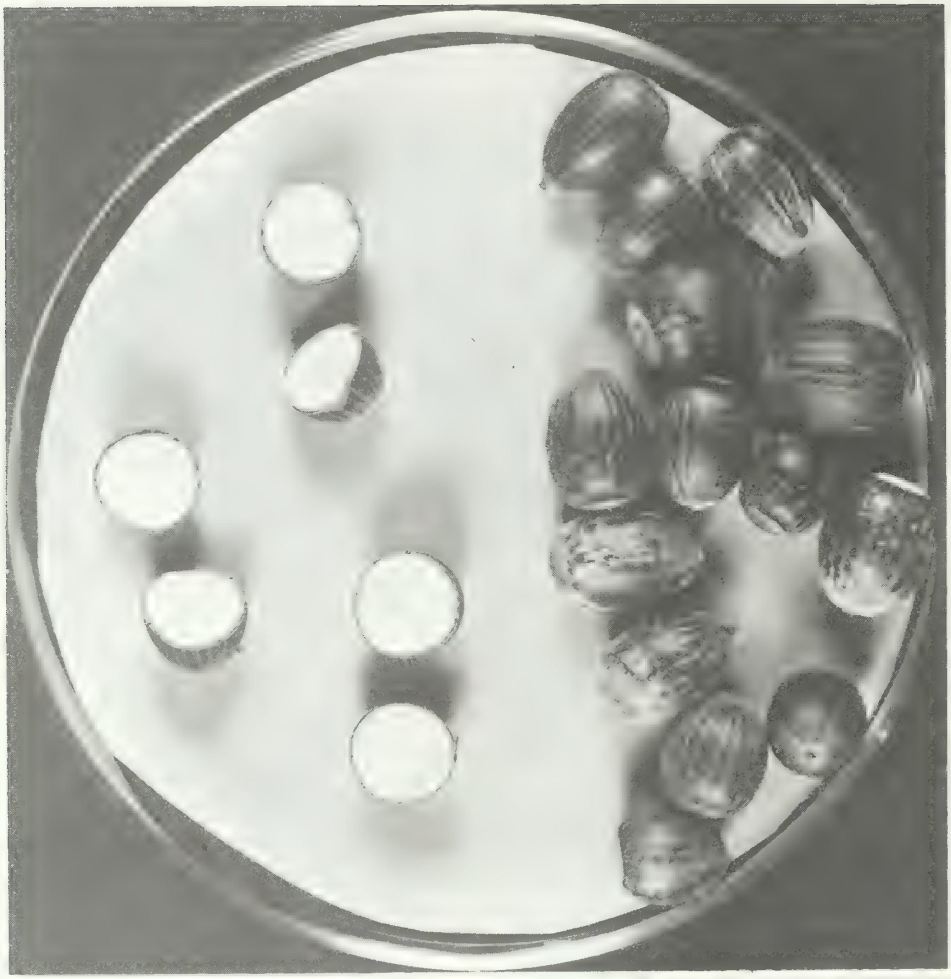

Figure 12.—*Acorns cut in half for germination testing.*

2. Peel the pericarp from the remaining half and place it on moist blotters, or similar material, cut side down.
3. Incubate at alternating temperatures of 20° (16 hours)/30°C (8 hours, with light). If only constant temperatures are available, use 25°C with 8 hours of light. Keep the test surface moist.
4. Count germination at desired intervals for up to 28 days. An acorn is scored as germinated if both radicle and shoot exhibit normal growth and morphology (fig. 13). Tests may be terminated early if germination is complete.

Although "percent of normal germination" is the primary performance measurement of the germination test, additional valuable information on acorn quality can be gained by some measure of germination rate. If germination is counted 2 or 3 times a week, expressions of rate—such as mean germination time (in days) or Peak Value (PV), where PV = maximum value of cumulative percentage divided by days of the test (Czabator 1962)—can be easily calculated. Both of these rate expressions have been shown to be significantly correlated with nursery germination of several southern oaks (Bonne 1984).

Removal of the pericarp in the "cut and peel" testing procedure essentially overcomes the dormancy i all oaks, so no stratification is needed for the test. Th minimum time to complete these tests is 3 weeks however, and time constraints may require mor rapid estimates of quality.

Rapid Viability Estimates

There are three options for quick tests of viability

1. *Cutting test*—The quickest estimate of acor quality can be obtained by a cutting test, and on should be carried out immediately after wate flotation of fresh acorns. Acorns should be cut i half to expose the embryo. Acorns with goo cotyledon color and no insect damage to their embryo are usually viable. Cutting tests are muc less accurate with acorns from storage, becaus

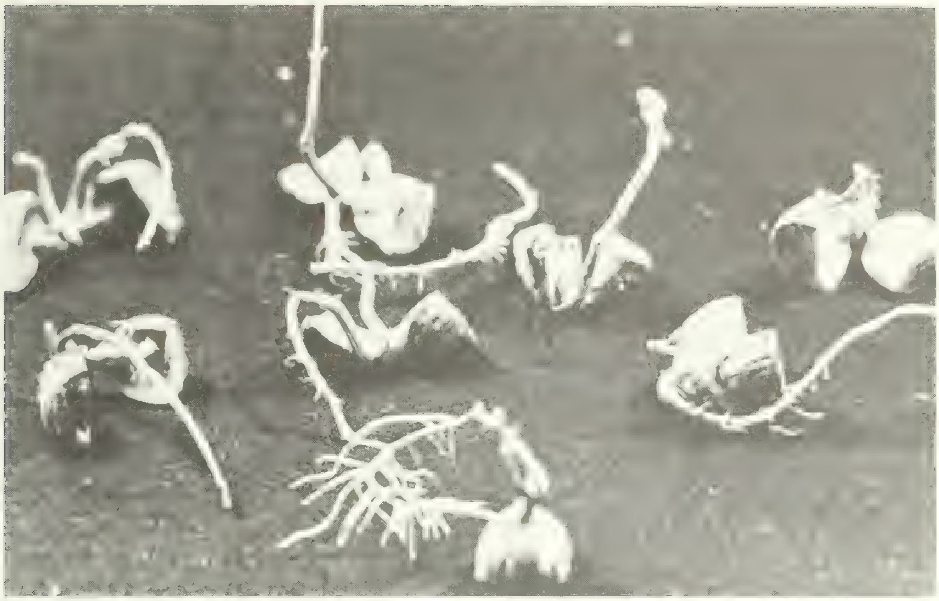

Figure 13.—*Normal germination in cherrybark oak. Normal growth of both radicle and shoot is evident.*

considerable decline in quality can occur without a corresponding change in cotyledon color.

2. *Radiography*—X-ray techniques can provide a quick, non-destructive test for damage or incomplete embryo development (fig. 14). Sample exposure and radiograph interpretation guides are available (Belcher and Vozzo 1979).
3. *Tetrazolium staining (TZ test)*—Tetrazolium chloride is widely accepted as a vital stain in seed science. The following procedures have been moderately successful for acorns (Bonner 1984):
   (a) Use two samples of 50 acorns each.
   (b) Cut acorns in half and discard the half without the embryo. Count and discard any rotten acorns.
   (c) Place acorn halves in a deep dish, micropyle end down, and add TZ solution until the halves are almost covered. Solution should be made with 2,3,5-triphenyl tetrazolium chloride and should have a pH of 7.0.
   (d) Cover dishes and incubate in the dark for 24 hours at 21° to 25°C. Break cotyledons apart to study stain in each acorn. A good stain is bright pink to red. Very dark red (as in blood) indicates tissue damage.
   (e) Score stain in five classes:
      I. Cotyledon and embryonic axis both stained.
      II. Axis stained, cotyledon unstained.
      III. Cotyledon stained, axis unstained.
      IV. Axis and cotyledon both unstained.
      V. Rotten or insect damage beyond recovery.

Class I is best, of course, but many acorns in Class II will also germinate. Class III acorns are very weak, and they normally will not produce plantable seedlings in nurseries. Some may germinate in greenhouses. Classes IV and V will not germinate, but in-

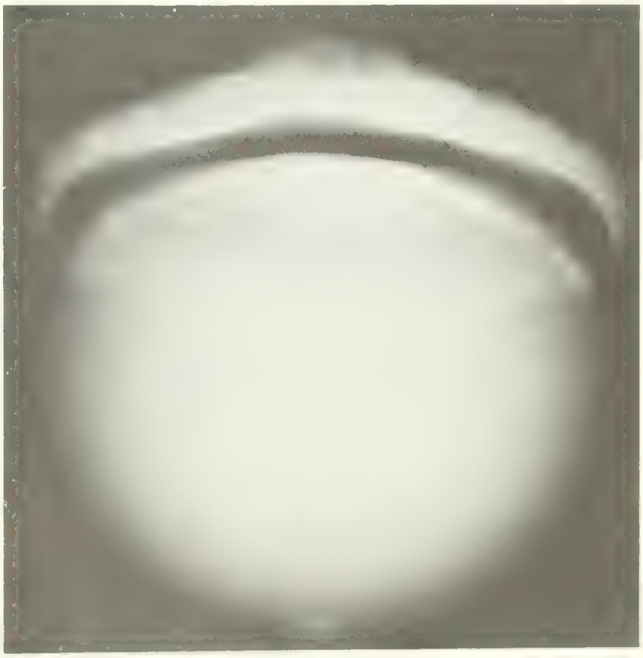

Figure 14.—*Radiograph of water oak acorn.*

clusion of the counts can show the overall quality of a lot.

Acorn characteristics of various species cause some problems in the TZ test. Water oak cotyledons fit together very tightly, thus restricting access of TZ solution to the embryonic axis. This species also has a tough testa next to the cotyledons, which restricts entrance of the solution. Similar problems occur with willow oak and Nuttall oak acorns. Scraping the testa away from the radicle area and removing more than one-half of the cotyledons might improve the condition. The more cotyledon removed, the more likely that the remaining pieces will separate when imbibed.

Cherrybark oak acorns do not present the problems described above. Their cotyledons readily separate when imbibed, and the testa on cherrybark acorns is thinner. Other red oak species that are more like cherrybark than water oak are Shumard and scarlet oaks.

Cotyledon color also influences stain interpretation. Healthy acorns with high lipid contents (water, willow, cherrybark) are orange, and the stain will show reddish-orange. Low-fat acorns (Shumard, all white oaks) have white to pale yellow cotyledons; good stains in these cases are typically pink to red.

Stain interpretation is very difficult on acorns in which the radicles are protruding through the pericarp when the tests are run. When these acorns are cut in half, the cotyledons frequently break apart and damage the axis. This condition is very common in white oak.

Moisture Content

Determinations of acorn moisture contents should be made as follows:

1. Draw two samples of about 10 acorns each.
2. Rapidly cut into halves (small acorns) or quarters (large acorns), mix, and weigh out a sample approximately equal to the weight of five acorns.
3. Dry at 103°C for about 17 hours in a forced-draft oven.
4. Cool the samples in a desiccator, reweigh, and calculate moisture content as the percentage weight loss of wet weight.

In official tests, if the duplicate determinations differ by more than 2.5 percent, they must be repeated until they do not (ISTA 1983).

Rapid estimates of acorn moisture contents can be made by drying cut samples in microwave ovens. Results may be 2 to 3 times more variable than regular oven measurements, but a single determination can be made in 5 or 6 minutes (Bonner and Turner 1980).

Detailed instructions for both types of moisture determination can be found in Bonner (1981).

Applying Test Results

Nursery practices are beyond the scope of this paper. Seedsmen should remember that, like other tree species, laboratory test results for acorns normally give higher germination values than will occur in the nursery. Local "experience factors" should always be developed for each species in each nursery. Without such information proper bed densities will be difficult to achieve. Recent recommendations of seedbed densities of 4 seedlings per square foot for cherrybark oak (Barham 1980) and white oak (Wichman and Coggeshall 1984) reflect the current preference for large oak seedlings for outplanting.

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This paper summarizes, in two parts, the results of research conducted from 1967 to 1983 on the seed problems of southern oaks, incorporating both published and unpublished results. Part I reviews current biological knowledge of acorns, and Part II recommends handling and management techniques for acorns of southern white and red oaks.

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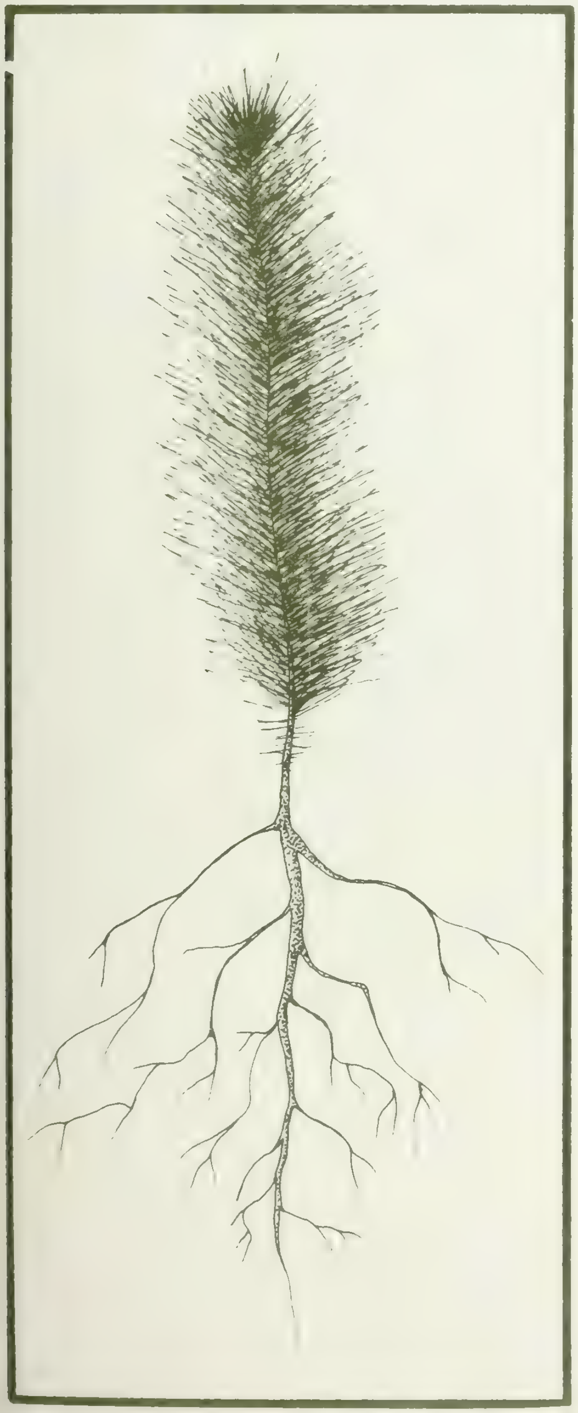
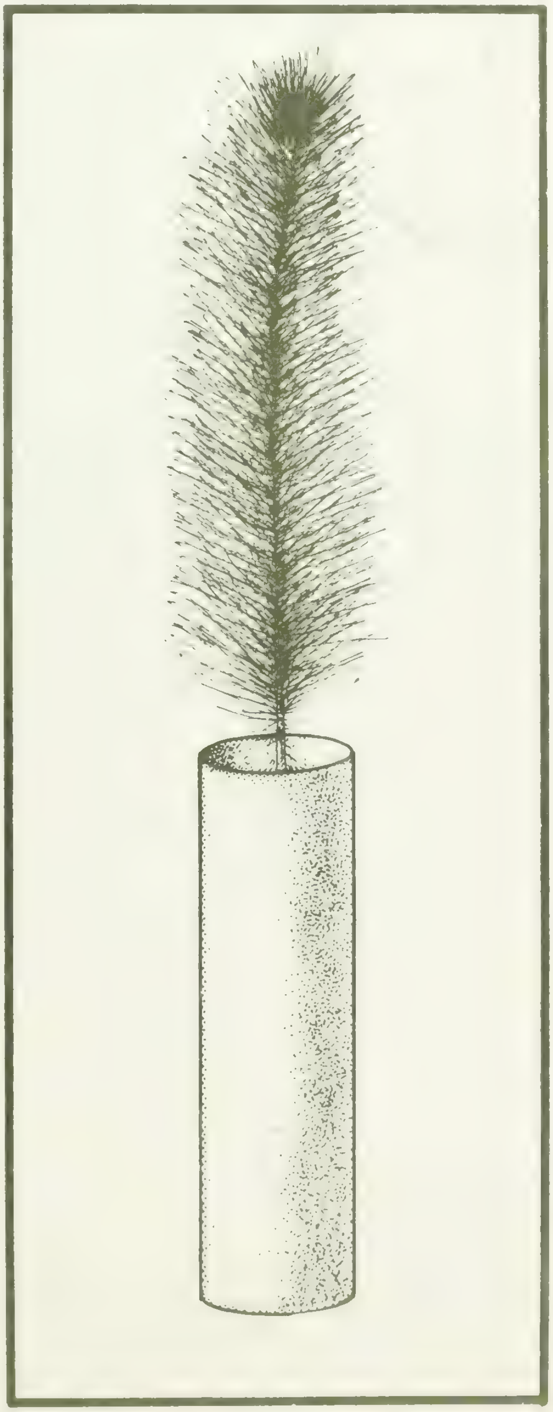
A Technical Guide for Forest Nursery Management in the Caribbean and Latin America

Leon H. Liegel and Charles R. Venator

An Institute of Tropical Forestry publication in cooperation
with the University of Puerto Rico





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This manual is the product of 20 years of nursery, plant physiology, and plantation research programs at the Institute of Tropical Forestry, Southern Forest Experiment Station, Río Piedras, Puerto Rico. The research was conducted in cooperation with the University of Puerto Rico.

October 1987

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A Technical Guide for Forest Nursery Management in the Caribbean and Latin America

Leon H. Liegel and Charles R. Venator

CHAPTER 1

I. INTRODUCTION

brest nursery stock is produced by bare-root and ainer systems. Healthy seedlings are grown in ter system if proper nursery management and cniques are used (fig. 1-1). Each system has two ls of operation: 1) the *traditional way*, which is ll-scale and usually hand-labor oriented, and 2) more *modern way*, which is large-scale and highly hanized. Level of mechanization in either system nds on available human and monetary resources the actual number of seedlings that will be ated.

1 Purpose and Scope

his technical guide[1] is a comprehensive summary frest nursery practices for the Caribbean, tropical atn America, and, to a lesser degree, other tropical res in the world. Included are actual and the auos' recommended practices, pointing out the adarages and disadvantages wherever possible with efic examples. Container and bare-root systems re iscussed since both are used in the region, somems interchangeably within individual countries. oever, guides for vegetative propagation techiqes are excluded, except for passing reference in om sections.

Te intent is to make the guide self-contained. Incued are both traditional and modern approaches, it as many mechanical alternatives as possible. oever, specific guides, such as fertilizer rates or herbicide rates, are difficult to prescribe because each country has its own problems with product availability and distribution.

1.2 Audience

The guide is *technical* because it is assumed that the readers are individual nursery managers or administrators who already have a graduate degree in forestry, agriculture, agronomy, crop science, or a related discipline and have practical nursery experience, at least in their own countries. Thus, all discussions are fairly detailed. More generalized guides are found in Chapter 7 of the Peace Corps Tropical America Reforestation Manual, now under editorial review. Definitions for pesticide (herbicide and insecticide) and other technical terminology are given in appropriate appendices or within individual chapters.

1.3 Subject Arrangement

This guide is divided into six major areas: 1) general stage setting for situations in the region, past and present, 2) overall nursery establishment and planning, 3) seed management, 4) small-scale (traditional) operations, 5) general management considerations, and 6) large-scale operations. Where subject overlap occurs within major sections, it is so indicated within parentheses.

Since each chapter is an individual unit, literature citations are placed after each chapter. For certain topics, more specific or "how-to-do-it" guides are given in various appendices. Rather than order these consecutively by numbering or lettering systems, a numbering system was chosen that refers to actual chapters where a topic is discussed in greatest detail or where it appeared first. For example, the first Appendix is number 4, because shading and nursery bed orientation are first discussed in Chapter 4.

Some subject matter overlap within chapters was intentional. For example, weeding and watering are critical concerns for early and later tending care of

---

[1] Fding for secretarial support was obtained from the U.S. gey for International Development, project AID/SCI/E2/06: rowh and Site Relationships of Caribbean Pine. . .in Costa Rica, mca, Trinidad, and Venezuela, 1982–87.

. Liegel was research soil scientist at the Institute of Tropical Forestry, Forest Service-USDA, Southern Forest Experiment Station, Call 000, Rio Piedras, PR 00928-2500, and is now at the Pacific Northwest Forest and Range Experiment Station, Forest Service-USDA, is, Oregon. Charles R. Venator was plant physiologist at the Institute of Tropical Forestry and is currently forestry advisor to Mexico, Forest Service, U.S. Embassy/Mexico City, P.O. Box 3087, Laredo, Texas.

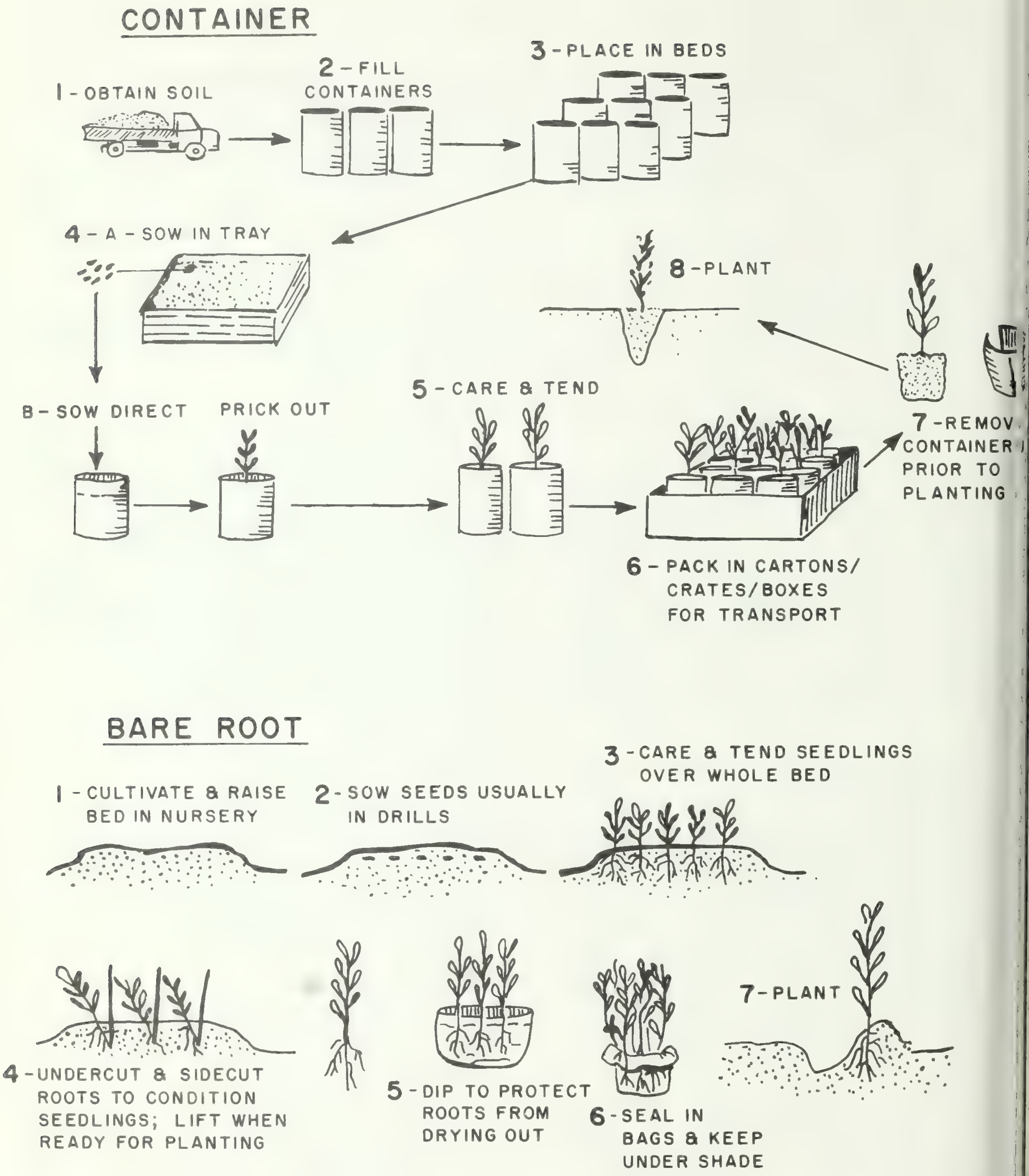
CONTAINER
1 - OBTAIN SOIL
2 - FILL CONTAINERS
3 - PLACE IN BEDS
4 - A - SOW IN TRAY
B - SOW DIRECT
PRICK OUT
5 - CARE & TEND
6 - PACK IN CARTONS/ CRATES/BOXES FOR TRANSPORT
7 - REMOV
CONTAINER
PRIOR TO
PLANTING
8 - PLANT
BARE ROOT
1 - CULTIVATE & RAISE BED IN NURSERY
2 - SOW SEEDS USUALLY IN DRILLS
3 - CARE & TEND SEEDLINGS OVER WHOLE BED
4 - UNDERCUT & SIDECUT ROOTS TO CONDITION SEEDLINGS; LIFT WHEN READY FOR PLANTING
5 - DIP TO PROTECT ROOTS FROM DRYING OUT
6 - SEAL IN BAGS & KEEP UNDER SHADE
7 - PLANT

Figure 1-1.—*Container and bare-root nursery procedures. Adapted from (1).*

h mechanized container and bare-root systems. wever, severity of the problem and effective cons are slightly different for each system; thus, these cs are discussed separately in each chapter.

Terminology

he terms "container" and "pot" are used interangeably throughout the text. Both refer to indiual or unitized entities containing some kind of wing material to support seedlings. Detailed akdown of various pot or container types is given hapters 9 and 15 and Appendix 15.

he terms "pot mix" and "pot medium" ("container " and "container medium") are also used interngeably, which may not suit the precise technical bulary of mechanized greenhouse operators. Yet terms are used throughout the region, reflecting usual practice of including more than one matea in the growing medium.

"lastic bag" is the shorter form of "polyethylene " The first form is retained throughout, except hre another kind of material is used instead of lethylene.

5 Source Materials

ost practical examples and illustrations are awn from forest nursery experiences in Puerto Rico. usery research in Puerto Rico has been quite extenv because the United States has provided continual ncial and personnel support for local reforestation ts since the early 1900's.

cluded, whenever possible, are examples and atices seen in the authors' travels in the Caribbean Latin America or related by visitors and Peace s workers in this region. Because local nursery agers travel little outside the region, appropriate ature citations from nursery research done in the n and African tropics are included as well. Such ences are not comprehensive but indicate the range of practices and problems existing elsee. Frequently, these citations will indicate other es that may be of interest to some readers.

.6 Physical Setting

e difficulty in prescribing specific nursery prac for individual countries is due in part to physical sity in the countries themselves. The "tropics" is arily delineated as areas between the Tropic of er and Tropic of Capricorn. This area is large and des geologically young, coastal plain soils; older cted and eroded uplands; and steep mountain es having young volcanic soils. Climates may be dry, almost desertic, to moist and very wet, all n relatively short distances (e.g., going from 700 to over 5,000 mm of rainfall annually within a horizontal distance of 185 km in Puerto Rico). Cultural values, traditions, and standards of living vary greatly as well.

As a result, the geological-soil-climatic-cultural mix of tropical countries is highly diverse and unique; generalizations are often difficult to make and support. For native workers and long-term residents of tropical regions, such diversity is normal and commonplace. When such diversity is overlooked, however, reforestation and nursery failures frequently occur because localized conditions do not meet idealized misconceptions of what tropical conditions really are. The authors have attempted to avoid overgeneralizations and misconceptions in this guide.

1.7 Dedication

This guide is dedicated to nursery managers and administrators throughout the Caribbean and Latin America. The authors hope that it offers them new ideas and alternatives for better utilization and more efficient use of their country's inherent natural, human, monetary, cultural, and social resources, both for short- and long-term planning.

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1. Evans, J. Plantation forestry in the tropics. Oxford: Clarendon Press; 1982. 472 p.

CHAPTER 2

2. REVIEW OF REGIONAL NURSERY PRACTICES

2.1 Puerto Rico

2.1.1 Traditional Approaches.—Designation of the Luquillo National Forest by President Theodore Roosevelt on January 17, 1903, signaled the beginning of a professional forestry program in Puerto Rico (*19*). In 1917, the U.S. Department of Agriculture (USDA) Forest Service was incorporated into the Puerto Rico Department of Agriculture and Works. In 1920, the University of Puerto Rico granted a small parcel of land in Rio Piedras for the first forest tree seedling nursery.

In its first year of operation, the nursery distributed 3,800 tree seedlings at no charge (*2*). Demand for seedlings increased so rapidly that by 1925 over

40,000 seedlings were distributed in 1 month alone. This total included 9,577 coffee seedlings. Shade tree seedlings for coffee plantations were also a significant part of the nursery's total production.

In 1926, a second forest nursery was constructed in Utuado; it produced coffee and shade tree seedlings. A third forestry nursery was established at the Polytechnical Institute campus in San German in 1927; it produced seedlings for private farms in western Puerto Rico. In 1928, the three nurseries distributed a total of 860,000 seedlings.

In 1934, tree distribution to private farms was put under control of the USDA Agriculture Extension Service. In 1936, a large model reforestation project was established on a private farm. This "Mercado project" marked a new direction for reforestation in Puerto Rico. Approximately 20 percent of the 7 million trees distributed went to private farms. Of these, 60 percent were considered commercial species (*2*).

2.1.2 Nursery Consolidation.—Forest tree nursery construction continued at a rapid pace. By 1940, 25 small nurseries existed (*2*), primarily on state forests. Then, in 1945, two centralized nurseries were built, one in the Luquillo National Forest at Catalina (fig. 2-1) and the other at Toa Alta. All small nurseries were eliminated.

During the Civilian Conservation Corps era and afterwards, Federal funds helped plant some 10,000 ha between 1934 and 1954. However, between 1954 and 1963 only 720 ha were planted (*27*). The number of trees planted per hectare generally ranged from 1,700 to 2,950.

The decline in forest tree seedling production, beginning in the 1950's and continuing until the present, had its roots in two different areas. First, tree planting until 1954 was done on degraded and deforested land acquired by the Puerto Rican government and set aside as public forests. By the mid-1950's, about 50 percent of this total area had been reforested by direct seeding with maria (*Callophyllum brasilensis*) and roble (*Tabebuia* sp.) seedlings or other species not suited for direct seeding. Second, private lands reforested in this period were usually large blocks abandoned from sugar cane plantations and coffee haciendas or lands acquired by consolidating small farms. By 1954, these areas were largely reforested to the extent desired by owners. The largest percentage of Puerto Rico remaining unforested in the 1950's belonged to small landowners who saw few economic rewards in reforestation.

In summary, the first quarter-century of nursery work in Puerto Rico was characterized by: 1) high dependence on hand labor techniques; 2) production of a very heterogeneous species mix of mostly hardwoods (e.g., about 75 species were used); 3) dependency upon U.S. Federal Government funds; 4) neglect of research; 5) exclusion of conifers except for a few Araucarias; 6) emphasis on producing coffee and c shade tree seedlings; and 7) emphasis on comme species like mahogany (*Swietenia* sp.), eucaly cordia (*Cordia* sp.), Spanish cedar (*Cedrela odor* teak (*Tectona grandis*), maria, and mahoe (*Hibi elatus*).

2.1.3 Nursery Centralization.—Seedling pro tion took on a new dimension in Puerto Rico w nursery operations for the entire Island were con dated at Monterrey, southwest of Dorado, in 1963 2-2A). The nursery was located on a flat coastal site having ample room for expansion. Improve for consolidating forest seedling production was in part with Federal funds.

Nursery production at Monterrey concentrate those species showing superior growth and perf ance in the late 1950's and early 1960's: Hond pine (*Pinus caribaea* var. *hondurensis*), kadam *thocephalus chinensis*), hybrid mahogany (*Swie macrophylla* × *S. mahagoni*), and mahoe. Operat were labor intensive, with all seedlings produce 10 by 25 cm vented plastic bags.

In 1975, to increase pine seedling production, a tainerized nursery operation (see Chap. 15) for duras pine was established in Santa Ana, near Alta. The intention was to separate forest seedling production from fruit tree production, w was also centered at Monterrey. Unfortunately, project was abandoned in 1979. Annual produ between 1976 and 1979 averaged about 300 seedlings that were grown in styrofoam block con ers.

Forest seedlings are now produced at Monterre the local Administration for Agricultural Prom and Development (AFDA) for the Forestry Area Puerto Rico Department of Natural Resources (D Plans were underway to increase pine seedling duction to 2 million annually by 1984 (fig. 2 using Styroblock and plastic bag stock. The maintains its own small nursery on the Cambal State Forest for mahogany, teak, and other woods (fig. 2-3). During 1980-82, an averag 500,000 and 100,000 seedlings were distributed a ally from the Monterrey and Cambalache nurse respectively.

2.1.4 The Catalina Nursery.—Bare-root hogany seedlings are still produced at the Cat nursery (fig. 2-1B). They are used in line plantin upgrade understocked natural forest lands withi Caribbean National Forest. During 1982-85, pr tion averaged 25,000 seedlings per year.

2.1.5 The Experimental Nursery.—The Instit Tropical Forestry (ITF) has maintained an ex mental nursery in Rio Piedras for almost half a tury (fig. 2-4A). Investigations from 1939 throug 1950's involved finding correct germination p dures and seed extraction and storage technique

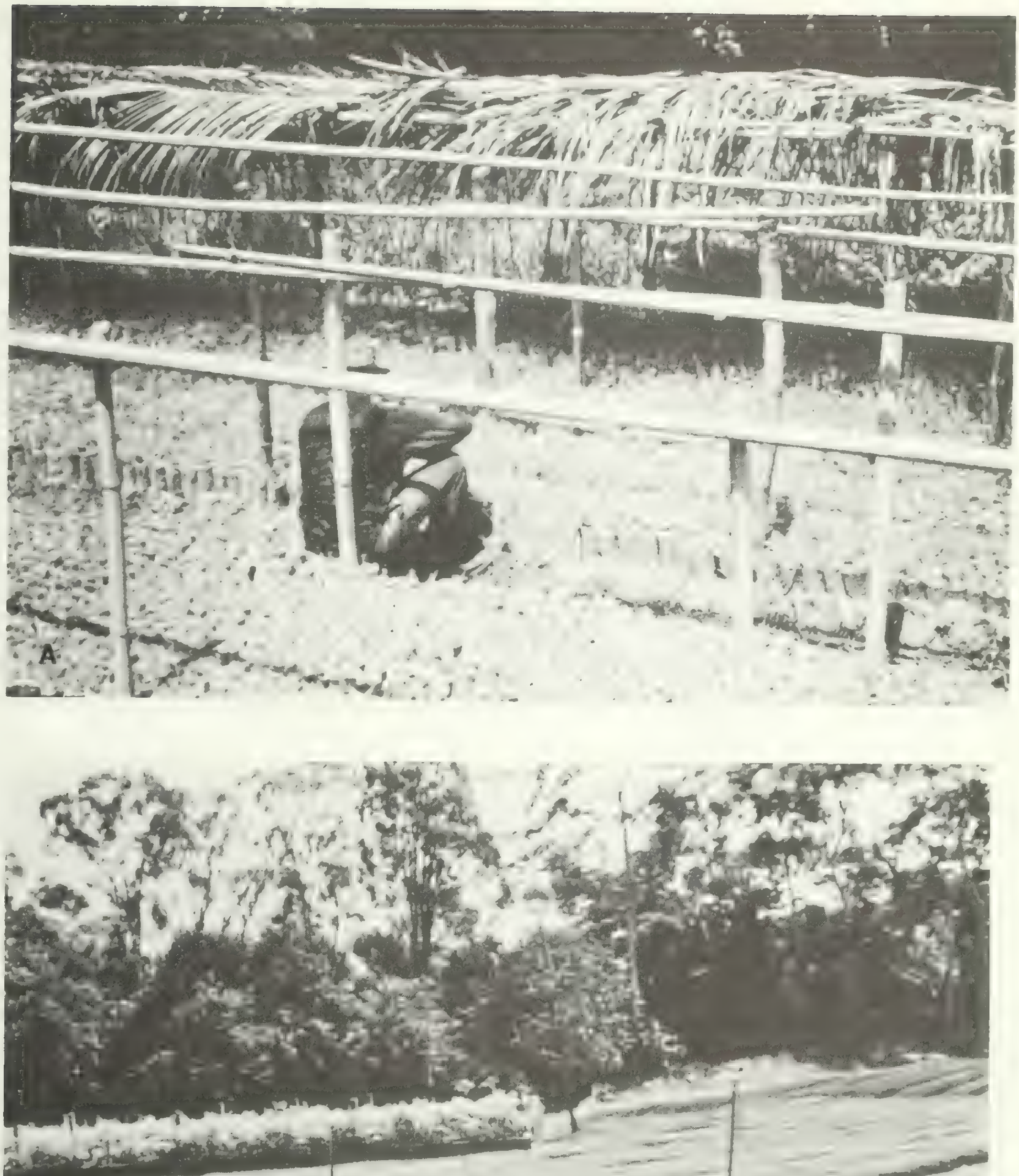

Figure 2-1.—*The Catalina Nursery. (A) From 1945 to 1963 it was one of two central nurseries in Puerto Rico producing forest tree seedlings for the entire Island. (B) Today (1986) the nursery produces bare-root mahogany seedlings exclusively for line plantings to upgrade natural forest lands within the Caribbean National Forest.*

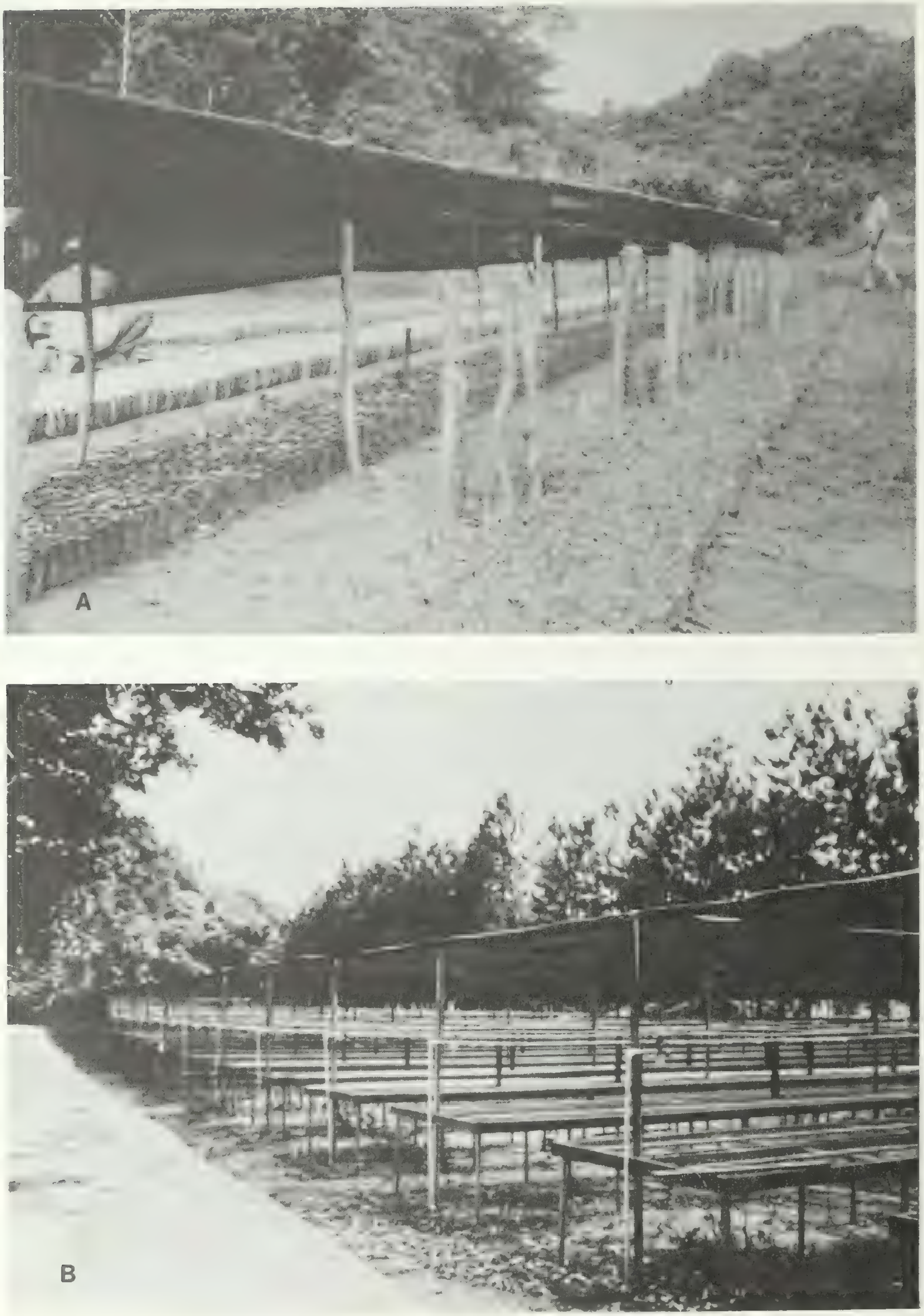

Figure 2-2.—*The Monterrey nursery in Puerto Rico. (A) As it appeared in the mid-1960's. (B) As it appeared in 1985.*

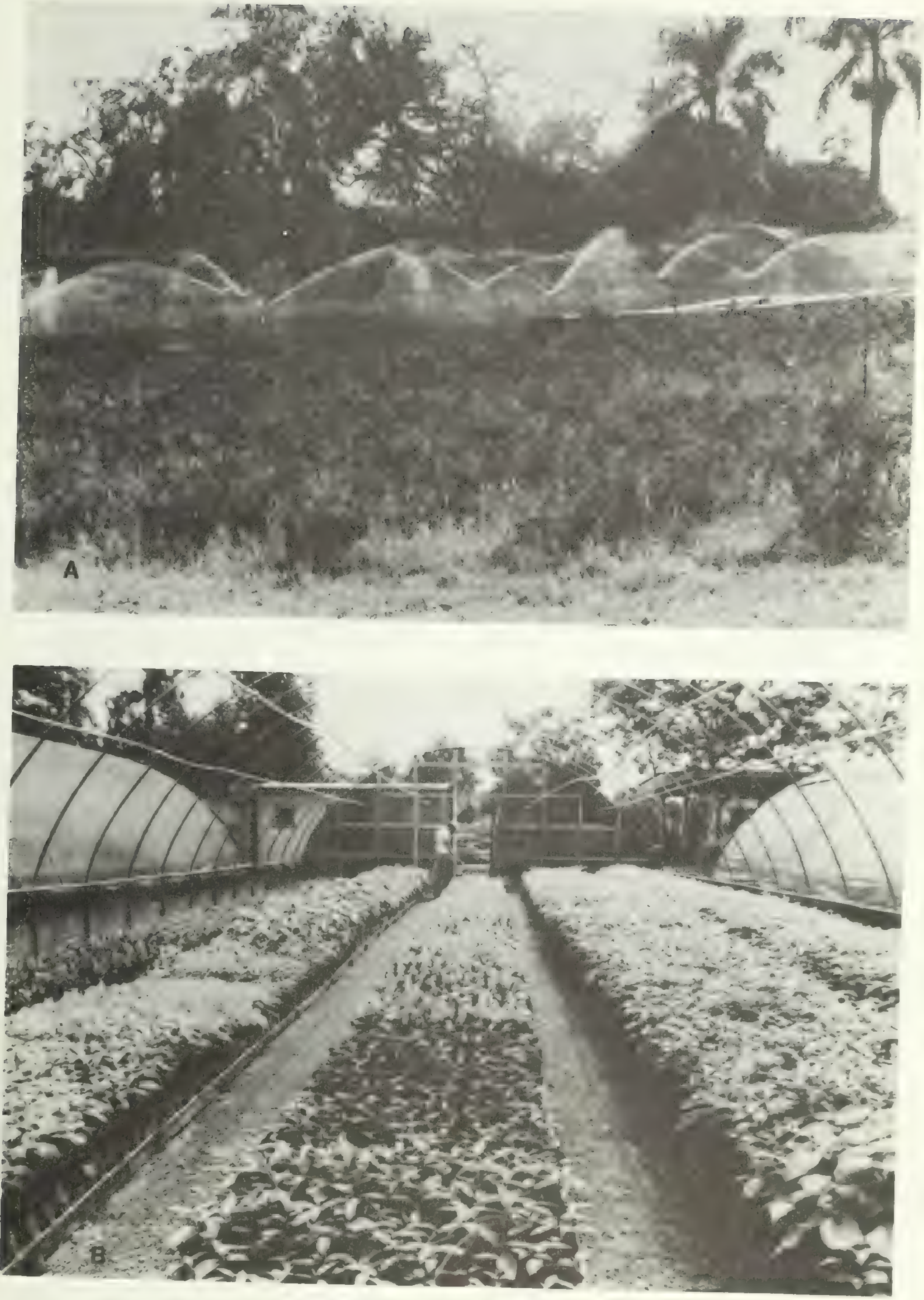

Figure 2-3.—*The Puerto Rico Department of Natural Resources Forest Division nursery at Cambalache State Forest. (A) Unshaded outdoor beds. (B) Beds where different shading intensities can be used.*

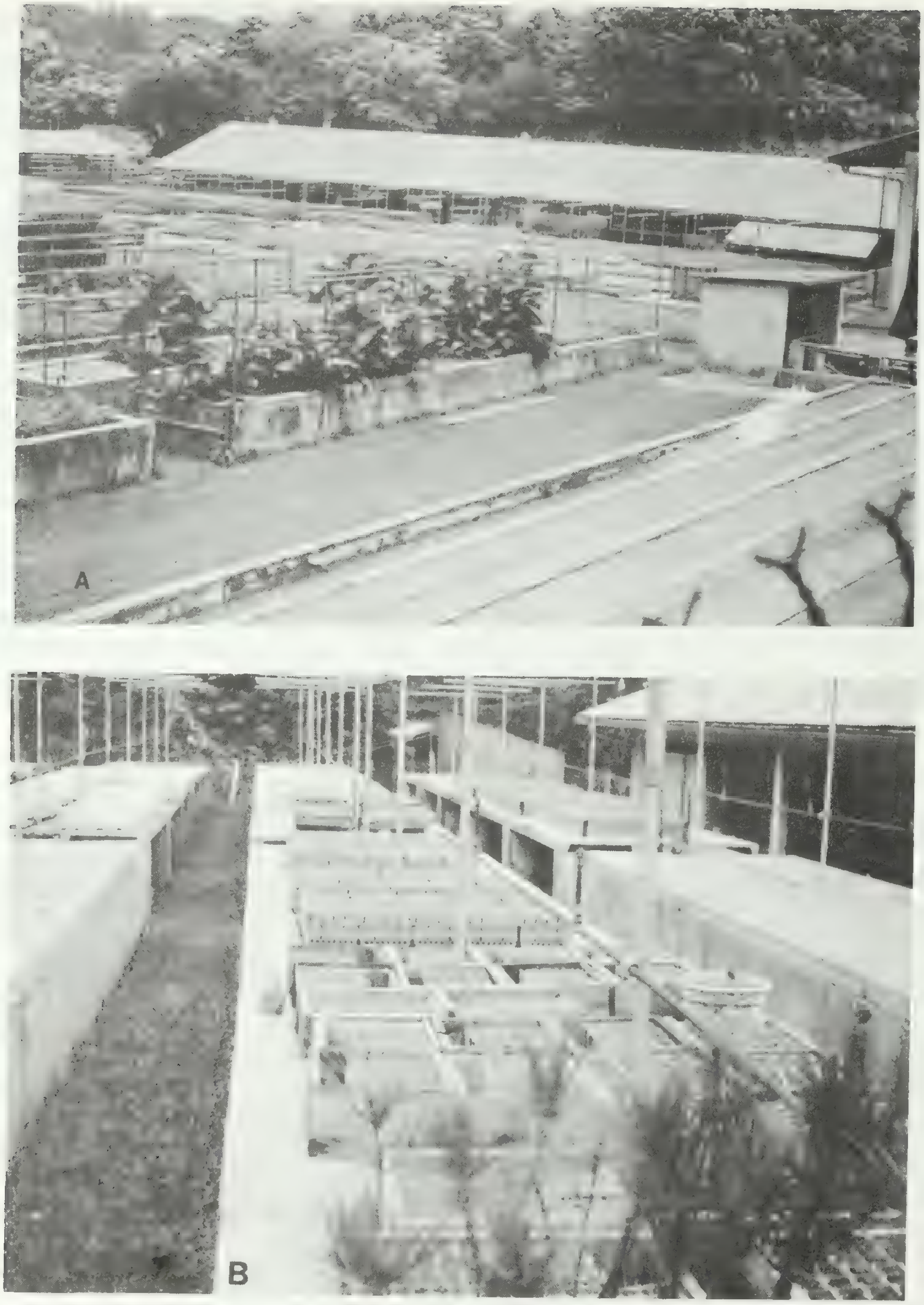

Figure 2-4.—*The Institute of Tropical Forestry (ITF) experimental nursery, Rio Piedras, Puerto Rico. (A) Overall view of facilities, 1970's through 1984; bare-root and raised-bench container beds (center); open-sided, covered work area (top); small beds irrigated from below (bottom, right); and central irrigation pump house (center, right). (B) Several container systems that were tested in the mid-1970's for* Pinus caribaea *and* P. oocarpa *provenances: Styroblocks, book planters, and polypots, in addition to the traditional plastic bag.*

16) for hardwoods and conifers tested in island- e adaptability trials (*17, 18*). This early work suc- sfully attributed poor pine growth across the Is- d to lack of native mycorrhizal fungi (*3*).

rom the 1960's through 1978, ITF nursery re- rch included germination tests and observations seedlings used for small field trials of kadam and *elina* provenances (C.R. Venator, unpublished ma- als at ITF); a local pine seed orchard (*7*); and inter- ional trials of mahogany (*22, 25*), teak (*4, 24*), and *aribaea* and *P. oocarpa* (*28, 29, 30*). Research on es included suitability of bare-root (*2*) and tainer-grown stock (fig. 2-4B) (*32*). Survival impli- ons of speed of germination, hypocotyl color and rophyll-a content, and emergence time of second- needles were shown for *P. caribaea* varieties. (*33*) no or other "abnormal" seedlings were also re- ed (*28*).

oday, ITF has no ongoing nursery research pro- n as it did from 1969 to 1978. Since 1979, only a hundred to 1,000 or 2,000 seedlings have been duced annually. The facilities are used for summer ent and thesis projects (*6, 26*) and short course ing exercises (*11*). A small seed bank is still ntained for storing and distributing seeds to other rnmental agencies for nursery research.

.2 The Caribbean and Tropical Americas

2.1 Traditional Approaches.—Traditional nurs- practices in Caribbean and Tropical nations are rally similar. Operations are labor intensive and l-scale. Forest Department or Forest Division manage the nurseries. The same staff provides nical assistance on where and how to plant lings that are usually provided at no cost (*1, 27*). seedlings are used to reforest blocks of land that, cut over for agriculture, are now idle or aban- d. Small landowners clear and plant several each year on private lands, and government ers plant crownlands (*21, 23*). Sometimes farm- eceive cash incentives for tree planting.

st countries have at least one small but perma- regional nursery that annually produces 10,000 ,000 seedlings of several species. In a large coun- ike Jamaica, a regional nursery may produce 00 to 1 million or more seedlings per year. On l West Indies islands, temporary "flying" nurs- are established for special projects on local ero- ontrol and improvement of understocked forests. g seedlings are brought in from a regional nurs- nd grow to outplanting size under temporary , sometimes one large tree (fig. 9-3). Or, instead ng germinated seedlings, naturally regenerated ings (i.e., "wildings") located close to the flying ry are dug up, transplanted into pots, and are o grow to outplant size.

Agroforestry plantings are common when farmers interplant trees with food crops. When cultivation stops, the small tree crop remains. In Haiti, where population density is high, land is scarce, and fuelwood is even scarcer, seedlings are given to or bought by farmers who tend them in small parcels with food crops (*14*). After 2 or 3 years, the fast-growing trees are cut for fuelwood or charcoal; some trees may be left for post and pole production.

The most common problem in traditional reforestation practices is failure to plant seedlings immediately after obtaining them. If seedlings are not watered and protected from the sun or desiccating winds, they will all die before or shortly after planting. Nursery stock in large containers can withstand harsher conditions than stock in small containers when delivered seedlings are not planted immediately. However, when large containers are used, fewer seedlings are delivered to each landowner. Pines and eucalyptus are generally produced in containers.

Using bare-root and stump nursery stock eliminates cumbersome containers and allows easier distribution of larger numbers of seedlings to individual landowners (*20*). Not all species are plantable as bare-root or stump stock. Commonly planted bare-root stock are mahogany and *Gmelina*; teak and *Gmelina* are also planted as stumps (fig. 11-5B).

Two well-known traditional container production systems are those using tarpaper pots (*34*) and plastic bags (*31*). The somewhat mechanized tarpaper pot system was developed in Surinam and was adapted later by several countries. Major drawbacks of tarpaper plots now are cost and availability of tarpaper. For small and highly organized reforestation projects where tarpaper is readily available, the tarpaper pot system may work well.

The plastic bag system is widely used in American, Asian, and African countries. Clear and dark plastic are available, with small (400 cc) to large volume (>3,000 cc) capacities. Bags are usually filled with alluvial soil. In Puerto Rico, Trinidad, and Jamaica, sugarcane waste (bagasse), rice hulls, vermiculite, and peat moss are mixed with soil or compost without soil.

Each country, and regional nursery within a country, follows different practices for tending seedlings, including shading and applying fertilizers. Specific examples are given in appropriate chapters of this guide.

The biggest difference between traditional nursery practices in Caribbean and Tropical American countries is the type of container used to propagate seedlings. Common methods in any country depend on past traditions and customs as well as local organization of seedling distribution and planting efforts. The major goal is to produce seedlings that can survive rigors of small scale operations. Highly efficient and

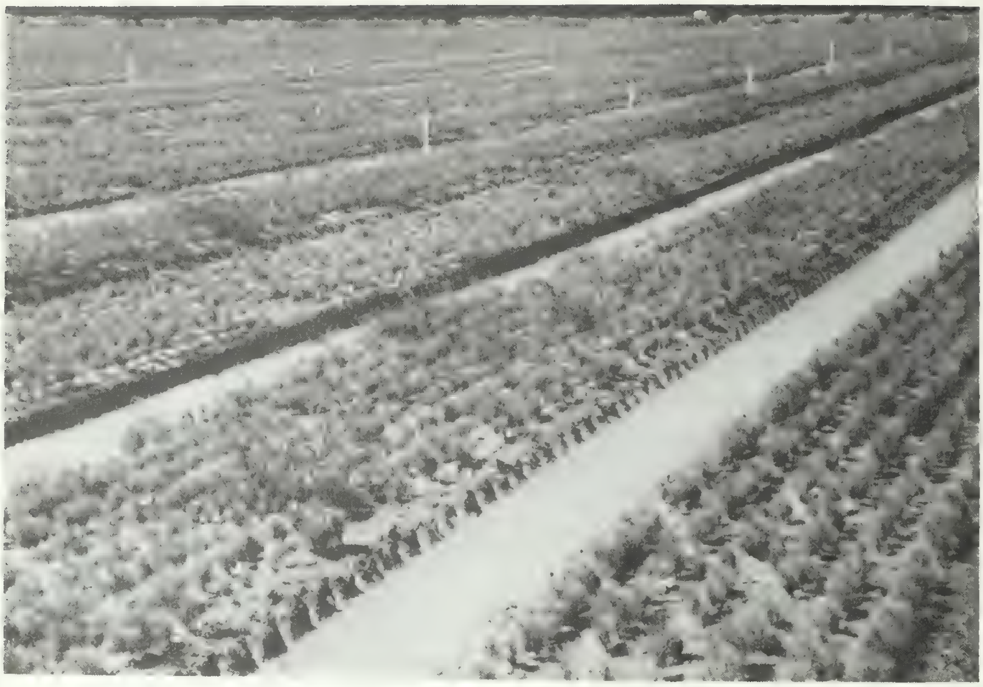

Figure 2-5.—*Large-scale, bare-root seedling production of Caribbean pine* (P. caribaea *var.* hondurensis) *by CONARE (Compañia Nacional de Reforestacion) in Venezuela's eastern savannas.*

cost saving techniques are available to nursery managers, but sometimes these conflict with other overriding community goals of providing employment.

2.2.2 Nontraditional Approaches.—Large countries with rising demands for wood products cannot obtain adequate numbers of seedlings for reforestation projects from small traditional nurseries. Instead, large-scale, semi- and fully-mechanized operations at large central nurseries produce millions of seedlings annually. Examples are Carton de Colombia's hardwood and pine plantings in Colombia's highlands (*12, 13*), CONARE's (*5*) operations in the eastern savannas of Venezuela with *P. caribaea* var. *hondurensis* and eucalyptus (fig. 2-5), and the JARI project's work (*8, 9*) in the Brazilian Amazon Basin with *P. caribaea* var. *hondurensis, Gmelina arborea*, and eucalyptus. In 1983, production was 30 million seedlings at three CONARE nurseries, each producing 10 million.

In large-scale operations, seeding, tending, lifting, and outplanting activities are highly organized. High outplant survivals require same-day planting of seedlings after lifting and transporting them to the field. Large-scale seedling production is suitable for both bare-root (CONARE-Venezuela) and containerized (Carton de Colombia-Colombia) nursery stock. Stump plantings were initially used for *Gmelina* at JARI in Brazil; yearly production once approached 1,000 ha and 1.3 million stumps. Before takeover by local Brazilian businesses in 1982, JARI field operations for *Gmelina* had changed to operational d
seeding on 500 ha.

Nontraditional, large-scale nursery operation
seeding, tending, and fertilizing are quite vari
from country to country. Practices used depen
species planted (hardwoods versus conifers),
(sands versus volcanic ash), local climate (dry ve
moist or wet), and outplanting technique (machin
by hand). Some of these large-scale practices ar
plained in detail in Chapters 15 and 16.

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CHAPTER 3

3. NURSERY SITE SELECTION

Nursery site selection is done with considerable care and caution. Many ecological and economic factors influence the success or failure of a nursery. As minimum requirements, each nursery site must have sufficient area, suitable climate and soils, adequate energy and transportation facilities, water of adequate quantity and quality, and available labor to produce healthy seedlings. Some factors discussed for site selection may not be important if a nontraditional mechanized system (Chap. 16), rather than either a traditional container or bare-root system, is chosen for operational use.

3.1 Climate and Environment

Preferred sites are those with favorable climatic and environmental conditions that are neither too wet nor too dry. Long-term rainfall and temperature data will indicate whether normal rainfall is adequate for growing seedlings. Windy areas should be avoided to minimize windburn and desiccation effects on seedlings. Constant whipping of seedlings by wind is detrimental to growth. In the dry season, plants are often watered daily to avoid desiccation, particularly young seedlings or those recently transplanted. Experience in Puerto Rico shows that dry, gusty, February and March winds will desiccate young pine seedlings less than 4 weeks old if they are not watered sufficiently. Locating nurseries in the Caribbean between 90 and 300 m above sea level and well away from coastal areas will avoid wind-laden salt contami tion.

On islands like Puerto Rico where predomin trade winds move from east/southeast to west/no west, nurseries are best located on west or northw slopes if flat protected valleys are unavailable. A w or northwest aspect provides greatest protection f wind, lowers evapotranspiration and creates more midity among seedbeds.

When environmental alternatives exist for est lishing forest nurseries, extremely dry areas, suc the southwestern coast of Puerto Rico, should avoided. Dry climates are unfavorable for f growing species like pine, eucalyptus, kadam, ce mahogany, and *Gmelina*. The number of shade- days in dry, semi-desert areas is also high, increas transpirational water loss from seedbeds. The nursery location in Puerto Rico is in the inte mountain range, which has the greatest numbe days in which rainfall exceeds 2.5 mm (*8*). Major lection criteria for nursery managers in count with predominantly dry climates (Haiti, Domini Republic) are adequate sources of irrigation wa and soils of low salt content.

3.2 Location and Essential Facilities

Locating nurseries close to major reforesta areas assures timely transportation of seedlings f nursery to field. Costs are reduced and fewer tru are needed if seedling delivery trips are short. T nurseries are usually located on major road syst connecting with planting areas. In Puerto Rico, ideal central nursery location is in the western pa the Island where the largest tracts of reforest land are found. For large operations, staff perso housing on nursery grounds deters vandalism, cre strong job identification, and facilitates wate plants on long weekends or holidays.

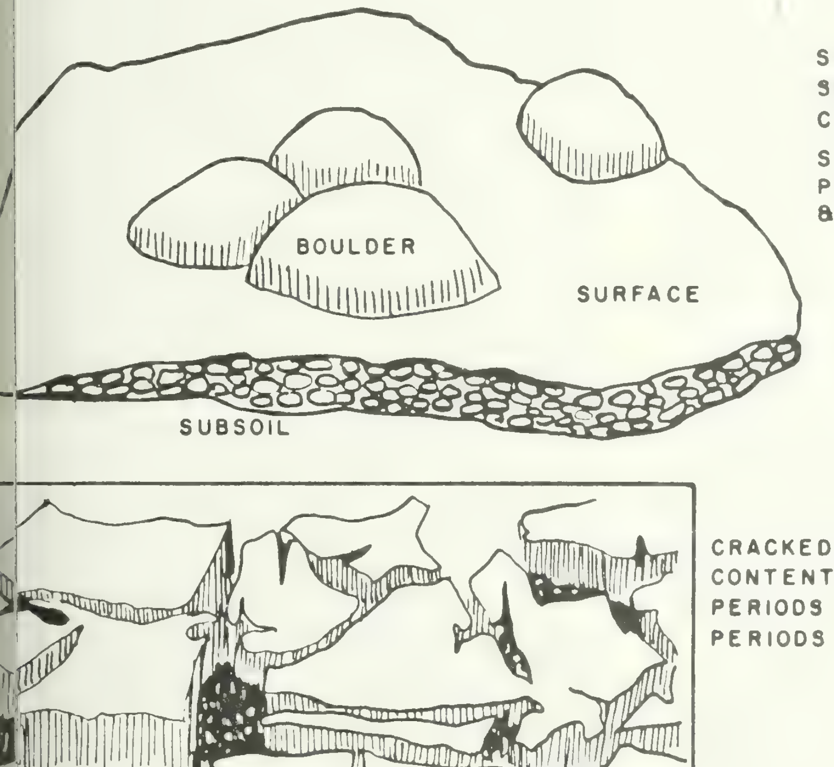
Large, mechanized nurseries must have elect power sources to operate equipment such as irriga pumps, refrigerators, potting machines, typewrit and lighting systems. Heavy machinery, inclu soil mixers, potting or packing machines, and s may require three-phase electrical lines. These costly to install if no lines exist close to the nur site. For areas without power or where power out are frequent, a diesel-powered generator may be essary.

Good communications are essential. If poss nurseries should be located close to existing telep lines or have radiotelephone communications tween nursery and central forestry administrativ fices. Such systems help coordinate field deliv from the nursery headquarters. Regular mail ser is needed to transmit seedling requests to the nur and to inform interested landowners of the avail ity of the nursery's current stock and prices.

Soils and Topography

or drainage control, nursery beds should have a to 1.0 percent slope; crossbed slope for the entire sery area can be 0 to 2.0 percent. Sites subject to ding and having rocky soils should be avoided (fig. . Soil scientists should be consulted throughout entire site selection phase.

3.3.1 Physical Conditions.—For a containerized nursery, soil type may not be an important site factor. However, soil is very crucial in selecting bare-root nursery sites because all drainage and trafficability problems, as well as ease in lifting seedlings, are directly or indirectly related to soil texture (*1*). Selection of a good nursery site must be based on soil survey data and actual field visits, not on easy access or



SURFACE ROCKS PREVENT USE OF SMALL MACHINES & RESTRICT BED CONSTRUCTION.

SUBSURFACE ROCKS OR "PANS" PROHIBIT GOOD ROOT PENETRATION & MAY INDICATE DRAINAGE PROBLEMS.

CRACKED SOIL INDICATES HIGH CLAY CONTENT & WATER SHORTAGE IN DRY PERIODS OR POOR DRAINAGE IN WET PERIODS

LOW AREAS & DRAINAGES ARE TOO WET IN RAINY PERIODS. CHOOSE AREAS WITH SLIGHT SLOPES SO THAT EXCESS RAIN DRAINS OFF SITE ADEQUATELY.

3-1.—*Poor nursery sites. Adapted from (9).*

economic advantage. In fact, because nurseries are long-term commitments, "sacrificing" the good physical and chemical properties of soils for other site factors such as closeness to paved roads or power lines *is not* recommended. These factors can be added later, whereas it is impossible to move a nursery once beds are contoured, water facilities are installed, and nursery buildings are finished.

In all cases, clay soils with high shrink-swell capacity must be avoided (fig. 3-1). Clay soils are also undesirable for raising bare-root seedlings because both large and small roots are broken during lifting (*4, 6*). Aeration is also poor in heavy clay soils, inhibiting seedling root development.

Soils that range between fine sand and sandy loam have the fewest problems related to soil texture. They do not readily compact as do clay soils. Other advantages of sandy soils are excellent drainage, fewer root rot problems, water more readily available to plant roots, easy tillage and no crusting-over following rains or irrigation, and suitability for heavy mechanical equipment used in constructing beds and maintaining healthy seedlings via various cultural activities.

When the nursery is contoured, all topsoil should be removed first and then replaced after grading is completed. Lifting properties of nursery beds are quickly altered if A and B horizons are mixed during plowing and grading operations. All physcial and mechanical analyses of soils at a potential nursery site should be done by a soil scientist on a well replicated basis (Chap. 14).

3.3.2 Chemical Conditions.—Soil acidity or reaction (pH) is probably the single most important chemical property of nursery soils. It directly affects other chemical reactions in the soil, the behavior of seedling roots, and soil micro-organisms around roots. Optimum pH varies according to the species grown. For tropical pines, the range is usually pH 5.5 to 6.0; when acidity drops below pH 5.0 or rises above pH 6.5, corrective action must be taken (*2*).

When soil becomes too acidic (below pH 5.0), lime ($CaCO_3+MgCO_3$) is added at rates usually ranging from 1 to 6 metric tons per ha. Actual amounts applied to any site depend on change in acidity desired, soil texture, and organic matter content. The kind of lime applied depends on the amount of available calcium and magnesium in the soil. Dolomitic lime is added to soils lacking both calcium and magnesium; calcitic lime is added when only calcium is needed. Soils too high in calcium and magnesium can induce trace element deficiencies in woody species. Acid-forming fertilizers such as ammonium sulfate or ammonium nitrate are added to lower high pH values (Chap. 13).

3.4 Water Supply

The lifeline of any nursery is the water supply.
produce seedlings that are ready for planting
beginning of the wet season, seedling culture m
begin at the end of the wet season and extend throu
the dry season. Unless sufficient water is availabl
serious problem can develop. Even small islands
have a wide variation in rainfall. For example, a nu
ery located on the dry, south coast of Puerto Rico u
ally has 260 to 300 rainless days or days with l
than 0.25 mm of rain and only 30 to 40 days of 2.5
of rainfall (*8*). Also important are the number of
versus dry months in each locality. A month is cons
ered dry if it receives less than 50.0 mm of rainf
Generally, artificial watering systems must be abl
provide a minimum of 100 mm per month for conif
and 200 mm for hardwoods.

The water supply must be monitored on a regu
basis to determine whether it contains excess salt
pollutants. If neither can be removed or lowered
acceptable levels, a new water supply is needed. W
water may be used, but in coastal areas excess
withdrawal may result in salt water intrusion to
aquifer. The ideal water source is a large pond
pollution free river from which water is pumped to
elevated tank and distributed under pressure throu
a sprinkling system. If a natural water source is
available, then treated water from a public wa
works can be used. However, proper authorit
should be consulted first to determine whether su
cient water is available. Also, the waterworks auth
ity has the technical expertise to determine whet
sufficient water pressure exists at the selected site
high-pressure irrigation systems.

Salts and calcium must be monitored in natu
water sources. Increases in both may raise soil al
linity that in turn favors growth of root rot organis
Conifers are more sensitive to excess calcium th
broadleaf tree species. When the potting medium
ceeds pH 7.0, conifers usually exhibit chlorosis
cause soil iron becomes less available. Under alka
conditions, young leaves often emerge yellow.
problem is intensified if a sodium or potassium nit
fertilizer is applied because potting medium alka
ity will increase even more. Soil or soil mixtu
above pH 6.5 are less favorable for mycorrhizal fu
growth and tend to favor pathogenic fungi that ca
damping-off.

3.5 Air

Air pollution is a potential problem for nurse
located close to highly industrialized areas or eve

l areas. Phytotoxic pollutants, including sulfur
ide (SO_2), hydrogen fluoride (HF), and ozone (O_3),
be carried downwind from their source onto a
ery and settle out directly on seedlings (*3*). Pollu-
s may also be carried great distances by wind and
be deposited on seedling foliage and possibly
e seedling death.

Labor

cause nurseries require skilled and unskilled
r, they must be located close to cheap and avail-
labor sources. If laborers must be brought in from
way cities, housed, and fed in work camps, ex-
es will be very high. Therefore, it is better to
e nurseries near towns or villages from which
ers can commute. Much nursery work is sea-
l. Workers living nearby can supplement their
ery income from other jobs in their villages or on
own small farms (*7*).

here project funds are limited, contracting for
production operations may be better than main-
ng a permanent or seasonal labor force, particu-
for traditional hand operations. Nurseries also
oy several kinds of skilled labor. Employees are
ed for applying pesticides or fertilizers, main-
ng seed storage and germinating operations, and
ting heavy machines and tractors.

ursery Equipment and Tools

ganization and layout of a nursery require space
orage and maintenance of equipment and tools
n adequate inventory system must be imple-
ed from the very beginning of nursery opera-
n If an inventory is not made and equipment not
nted for, many tools will be either lost or stolen
urchased in duplicate when they cannot be lo-
Time and money are wasted when tools or
ment are not readily available. One person
d be given responsibility for equipment issue,
val, operation, maintenance, and repair.

imonthly maintenance and preventive mainte-
schedule for major equipment should be imple-
ed. For example, compost shredders, soil mixers,
anical bag fillers, etc., should be greased regu-
and covered to avoid dust accumulation during
ge. When rust appears, equipment should be
d and repainted with rust-inhibiting paint. In
oist and wet tropics where deterioration of me-
al devices is rapid, repainting schedules are fre-
. In all climates, preventive maintenance is the
ay to prolong the life and use of nursery equip-
n

equipment inventory should be taken immedi-
after the planting season has ended or at the
st appropriate time thereafter. Thus, the nurs-
anager will know well ahead of time when to purchase equipment or supplies for the next season.

Some of the basic tools and equipment needed for a tropical nursery are listed below. The list may not be exhaustive for certain specialty nurseries; however, smaller traditional nurseries in developing countries can accomplish much with only a few of the items listed.

Adding machine
Adze
Anemometer
Apron, cloth
Apron, rubber
Auger, soil type
Autoclave, pressure cooker type, wooden and rubber
Balance, analytical
Balance, bar
Balance, spring type
Baskets, metal
Baskets, woven
Bench, sitting
Binoculars
Blackboard
Boots, rubber
Boxes, wooden bottom
Boxes, wire mesh bottom
Buckets, galvanized
Buckets, plastic
Burlap, bags and rolls
Cans, gasoline
Cans, watering
Carpenter supplies and tools
Chain saw
Cloth bags
Containers, large capacity measuring
Containers, polyethylene
Containers, tin
Crowbar
Cutters, wire
Desk lamps
Drafting supplies
Drilling, electric, plus bits
Drums, 208-liter, several
Electronic calculator
Electric bag sealer
Electric fan
Electric grinder
Files
Filter paper, for seed germination
Fire extinguisher
First aid cabinet
Flats, galvanized
Forklift
Freezer, for seed storage
Funnels
Germinator
Gloves, cloth
Gloves, rubber
Goggles, industrial type
Graduated cylinders
Grafting tape
Hacksaw and blades
Hammers
Hammer mill, large capacity
Hand cart
Hand lens, 10×
Hormone for vegetative propagation
Hygrothermograph, recording
Knives, grafting
Knives, pruning
Labels, dagger type
Labels, plastic slip-on
Laboratory chemicals and glassware
Machetes
Mallets
Masks, respiratory
Metalworking equipment
Microscope
Mirror
Mixer, soil
Nails, galvanized
Nozzles, fogg-it type
Office supplies and equipment
Petri dishes
pH meter, electronic and portable
Pickaxe
Pitchforks
Plastic trays, for seed germination
Pliers
Polyethylene bags
Polyethylene sheeting, black
Rakes, garden
Rain guage station
Rasps, wood

Refrigerators
Rulers, metric
Saran shade, 20, 30, and 50 percent
Saw, electric
Screwdrivers
Seed blower
Seed divider
Seed moisture tester
Seed separator
Seed sieve
Shovels
Shredder, for compost
Side cutters
Soil moisture tester
Soil sieves, large capacity
Soil sterilizer
Soil thermometer
Soldering equipment
Spray tanks, 11-liter, for fertilizer and pesticides
Stakes, wooden, treated
Storage bins
Tables, wooden or metal
Tape measures
Test tubes
Thermometers, recording
Tractors
Vise
Wagons
Welding equipment
Wheel barrows
Wire, galvanized
Wire mesh, 6-mm & 13-mm sizes
Wrenches, plumbing type

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CHAPTER 4

4. DESIGN AND LAYOUT

A permanent nursery is a long-term commitme and investment. As much care and caution should used in designing a nursery as in choosing a si Foresight in design and layout will increase efficien in growing seedlings and in minimizing lost time personnel.

Actual design and layout depend on whether nursery produces bare-root or containerized see lings, uses mechanized or nonmechanized techniqu and has a large or small capacity. Anticipated ope tion as a commercial ornamental (*2*) or commerc greenhouse (*6*) is also a concern.

4.1 Production Areas

Nursery production areas are dedicated to actu growing of seedlings, whether in mounded or grour level bare-root beds, raised or ground-level contair yards, or germination and propagation plant shelte In small traditional nurseries, production areas ma up 90 percent or more of the total nursery area (4-1). In large bare-root nurseries, as much as 50 p cent of the production area may be left fallow ea year (Sec. 16.1.2).

Production efficiency is achieved by locating ea major operation in a specific area of the nurse Within each area, fallow or unused beds may ex from year to year. In large operations, areas shou include space for expansion. Bare-root beds are ways located in those areas having the best soil che ical and physical properties.

Production area size depends on several fact General considerations are size of entire complex, pected yearly production rates for species grov seedling density in beds, kind of equipment used, whether bed orientation is square, or rectangular parallel, or diagonal to major buildings (*2*, *3*). bare-root beds, specific considerations include number of rows in each bed, seedling spacing in e row, and minimum aisle width needed to accom date equipment or hand labor. For container be

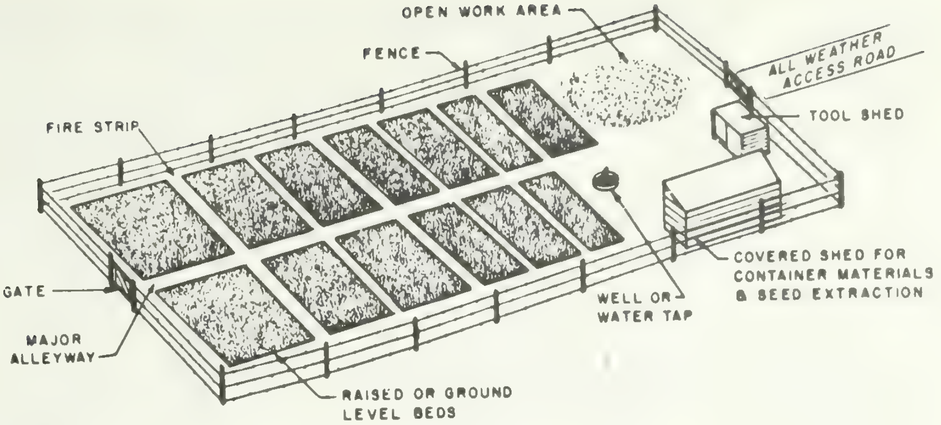

Figure 4-1.—*Generalized design and layout of a small traditional nursery. Most of the area is production oriented because operational, storage, utility, and communication areas are minimal. Adapted from (7).*

fic considerations are whether beds are raised or
nd-level type, have hard or soft surfaces, have
or narrow benches, and whether containers used
nitized or individual cells (figs. 15-1 and 15-6).

dministrative/Employee Areas

ese areas should be located close to major access
. Routine movement of personnel and vehicles
d not disrupt other operations (*5*). For example,
ate internal access roads for employee, delivery,
achine traffic are possible, as are separate facil-
trances for field workers and visitors. Separa-
f administrative and nursery worker facilities
ge areas, rest rooms, etc.) is another alternative.
in common areas for parking, recreation, and
provide opportunity for interaction between
ry workers and administrative personnel about
al interests and problems.
le of operation dictates need for special facilities.
nurseries have residence areas and an infir-
a part-time nurse or doctor may be on call cer-
days or daily. Such facilities should be close to,
parate from, other buildings to ensure the pri-
and well-being of persons needing them.

torage-Shipping-Receiving Areas

se areas are the hub of most nurseries because
eceive all raw materials for producing nursery
Access roads should be wide, all-weather type,
ee of curves (fig. 4-2). Turn-around areas are
d for trucks entering and leaving the facilities.
age facilities must be large enough to accommo-
aily raw material needs as well as spare parts
all equipment (grinders, power saws, mowers,
Machine sheds and work areas for servicing
equipment are best located away from main
es.

4.4 Operational Areas

Other areas are required for extracting, drying, and processing seed; preparing germination trays and pot mix; screening compost; filling pots; and washing, grading, and packaging seedlings (*7*). The key concern for these areas is maintaining flexibility and integrated flow of activities (*1*).

Flexibility means the willingness to incorporate new machinery and procedures as needed to increase production or to change kinds of seedlings grown. It is best to overbuild new facilities to accommodate future activity shifts.

Integrated flow means arranging buildings, walkways, roadways, alleys, etc., to complement each other. For example, compost pits should be close to compost screening and mixing areas. Space is saved by *intentionally* designing certain areas to accommodate several activities. Open-air seed drying areas also serve for filling pots in good weather; covered, open-sided buildings double as lunchrooms and places where small construction jobs (e.g., making germination tray shade boxes) are possible in bad weather (fig. 4-3).

4.5 Herbicide and Insecticide Storage

Chemical storage areas are specialized operational areas because materials stored in them have toxic or caustic properties. All chemicals, including insecticides, fungicides, and herbicides must be protected from environmental elements. Suitable storage areas must be:

- located in separate buildings away from other areas used by humans and animals;
- constructed of fire-proof materials and hard-surfaced shelves and floors;
- accessed only by authorized personnel;
- kept dry, cool, and well-ventilated; and
- posted with proper signs advising of dangerous area (fig. 4-4).

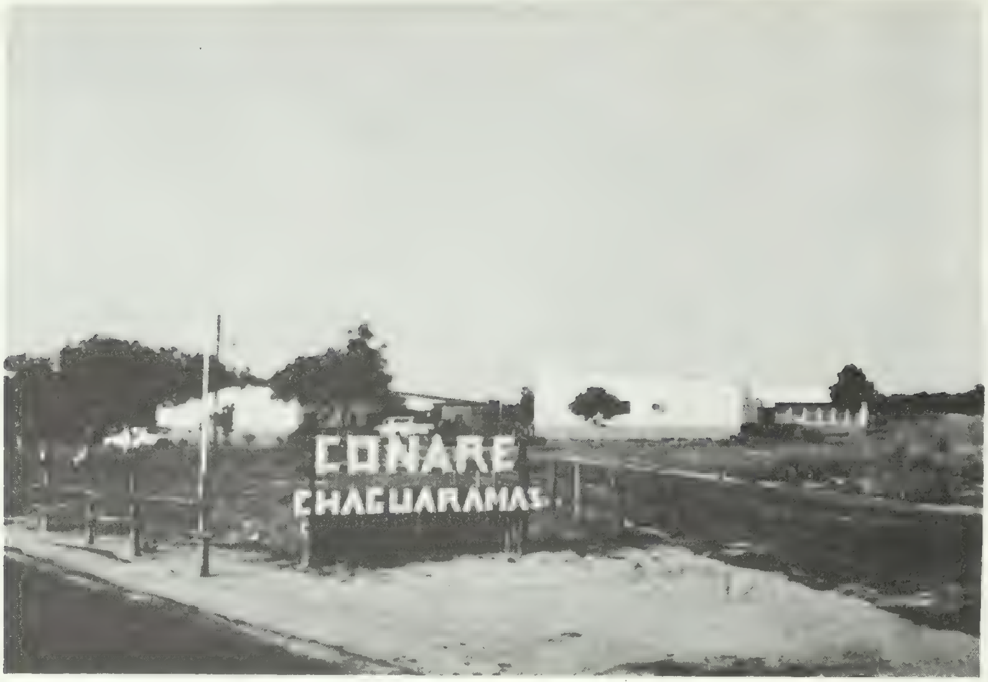

Figure 4-2.—*Hard-surfaced, split-access road to nursery facilities of CONARE (Compañia Nacional de Reforestacion), Estado Monagas, in Venezuela's eastern savannas. Right fork goes to laboratory and administration area; left fork goes to employee residence, meal, and recreation facilities. Not seen is a dirt road off left fork that leads to machine shop and storage area.*

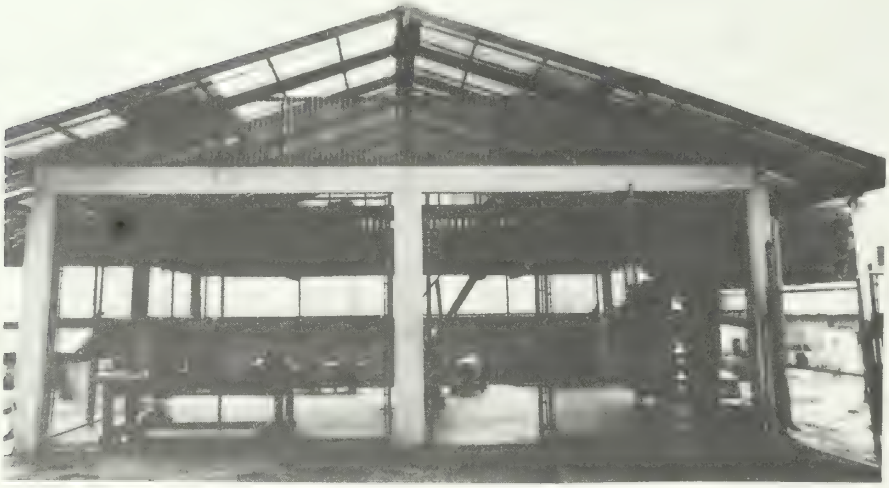

Figure 4-3.—*Covered, open-sided nursery building that also doubles as lunchroom, seed extraction and drying area, and carpentry area for making small items such as shade frames for germination trays.*

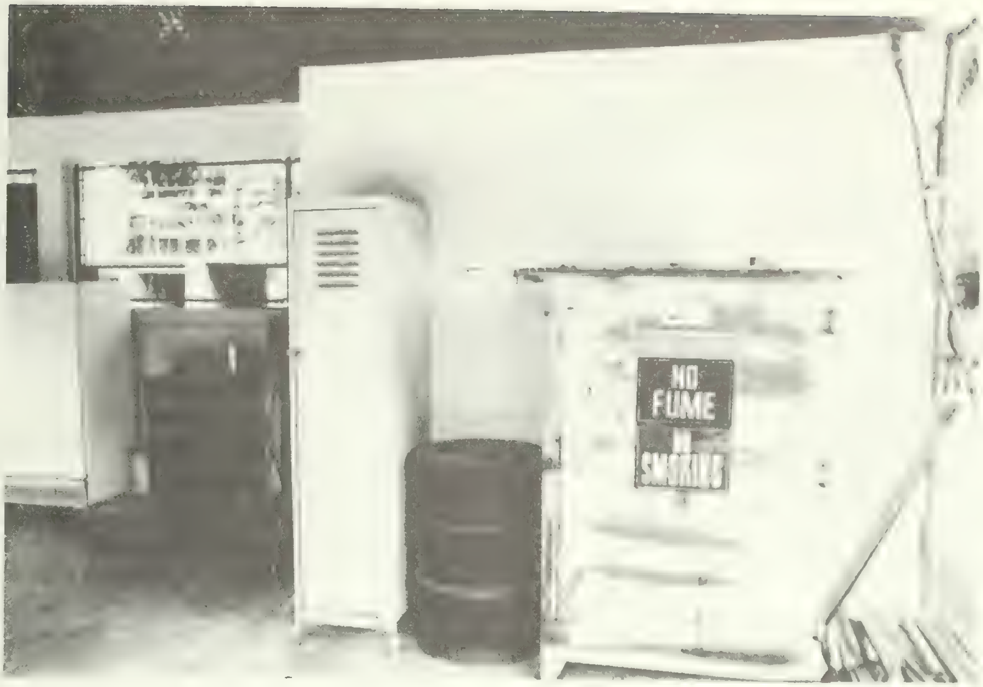

Figure 4-4.—*Pesticide and herbicide storage areas should be clearly marked, left dry, and kept locked when not in use.*

Insecticides and herbicides are always stored *sepa- tely.* All chemicals are stored in their original con- iners to avoid confusion with other products. Con- iner lids or caps are tightly closed to prevent olatilization of liquids and escape of toxic fumes. If aks are found, cleanup of remaining material and aste is done by following indicated label and stand- rd safety instructions, using safety equipment nasks, gloves, respirators) when needed. For certain azardous materials, local authorities may have to uthorize final disposal. An up-to-date inventory nould be kept of all chemicals, showing remaining mounts of liquid, solid, granular, and gaseous mate- als. At least one supervisor and one worker should e trained in all aspects of chemical use, storage, and andling so that routine and emergency procedures re understood and practiced.

.6 Laboratory Facilities

Laboratory space is only essential for large nurs- ries. It provides a separate area to conduct pretreat- ent germination and storage experiments on seed, test for soil pH and dissolved salts, and to monitor edling nutrition at different stages of growth.

When many tests are planned, laboratory space ay require two or more rooms. Soil screening and ed extraction procedures are "dirty" activities as- gned to one room; "clean" chemical tests and proce- ures are performed in another. Clean and dirty labs are best located in separate buildings or different areas of the same building. Sensitive equipment (pH meters, spectrophotometers, atomic absorption units, etc.) requires continuous air conditioning to avoid corrosion of instrument parts in humid tropical climates. Other special needs for nursery labs are:

- apparatus for making distilled water for chemical tests;
- fluorescent lighting;
- voltage regulators to reduce power surges where electrical power interruptions are common;
- corrosion-resistant pipes in sinks where acid or alkaline chemical wastes are dumped;
- scrubbers to clean toxic elements from fumes vented to outside areas;
- corrosion-resistant exhaust fans to direct harmful fumes away from seedlings, parking lots, and communal work or recreation areas; and
- cold storage to preserve chemical reagents, extractions, and materials needed in soil and seed testing experiments.

4.7 Utility Lines

Good design and placement of irrigation and electrical lines keep production efficiency high by reducing maintenance and repair costs. For example, locating irrigation pipes and pumps near production areas reduces both original and replacement piping costs (fig. 2-4A). Shutoff valve locations should be shown on maps of the nursery complex to help control emergency situations when leaks occur. Placing supports of overhead pipes away from roads and tractor alleyways reduces accidental breakage of water lines.

Corrosion-resistant fittings are essential for water lines and pumps. If irrigation water has high dissolved salts, large aperture nozzle fittings are required. A large supply of nozzles is needed where corrosion is a big problem.

Power and telephone lines are best placed underground to avoid potential damage from vehicles and storms. If overhead lines are used, they should be kept away from production areas and alleyways. When feeder power and telephone lines are placed in production areas, trenches must be deep and well marked, particularly in bare-root beds where tractor-drawn machinery is used. All water, power, and communication line locations should be clearly marked on overlays of the nursery complex blueprints.

4.8 Protection

4.8.1 Windbreaks.—Windbreaks are planted on windward sides of production areas and germination beds to reduce drying, eroding, and abusive effects of winds on growing seedlings. Ameliorating effects of windbreaks extend several times the height of mature trees (*4*). Large nurseries need several lines of windbreaks to adequately protect seedbeds. Usually, species different from those produced in the nursery are used because their seeds germinate like weeds and reduce effects of using improved seeds.

Species with large spreading root systems and crowns are not suitable. Shade from them reduces sunlight on nearby seedbeds; spreading root systems compete with bare-root seedlings for water and nutrients. Any insect or disease outbreak in windbreaks should be controlled quickly to reduce risk of spread to nearby nursery seedlings.

4.8.2 Shade and Nursery Bed Orientation.—An east/west orientation may be better than traditional north/south bed orientation in the tropics if individual, small covered beds are used rather than widespan shade houses. Justification for east/west orientation is based on: 1) need for some shade during the hottest part of the day and 2) minimizing the amount of shading material needed to provide shade protection for seedlings. Modern nursery management concepts also emphasize fostering as much environmental control as practical to reduce dependence upon nature's whims.

Puerto Rico lies at approximately 18° N. latitude from the equator. For maximum interception of the sun's rays, the shade roof should be tilted about 18° towards the sun. In other words, the north side of the east/west oriented shade roof should be higher than the south side (see Appendix 4 for a schematic view of inclination direction).

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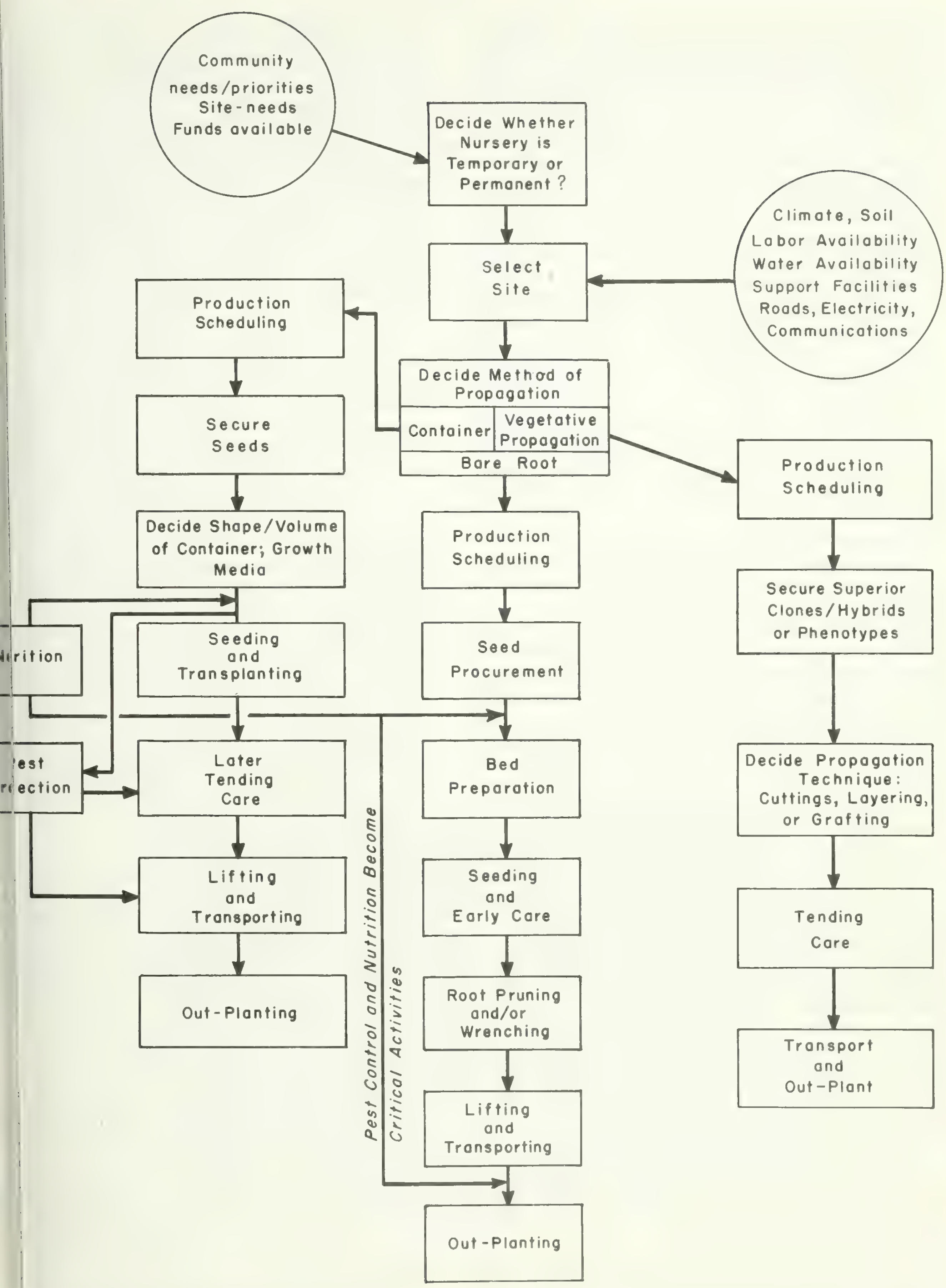
CHAPTER 5

5. PRODUCTION SCHEDULING

5.1 General Principles

The key to a successful nursery program is p
ning and developing realistic timetables for all ph
of seedling production; this is called produc
scheduling. Schedules are based on knowledg
nursery physical plant limitations and manage
experience. A detailed production and plann
schedule like that described in Appendix 5 ca
developed for large, mechanized operations.
smaller nurseries, a simple flowchart shows esse
elements of seedling production (fig. 5-1).


Community needs/priorities Site-needs Funds available
Decide Whether Nursery is Temporary or Permanent ?
Climate, Soil Labor Availability Water Availability Support Facilities Roads, Electricity, Communications
Select Site
Decide Method of Propagation
Container
Vegetative Propagation
Bare Root
Production Scheduling
Secure Seeds
Decide Shape/Volume of Container; Growth Media
rition
Seeding and Transplanting
est
rection
Later Tending Care
Lifting and Transporting
Out-Planting
Pest Control and Nutrition Become Critical Activities
Production Scheduling
Seed Procurement
Bed Preparation
Seeding and Early Care
Root Pruning and/or Wrenching
Lifting and Transporting
Out-Planting
Production Scheduling
Secure Superior Clones/Hybrids or Phenotypes
Decide Propagation Technique: Cuttings, Layering, or Grafting
Tending Care
Transport and Out-Plant

ur 5-1 *Flowchart of procedures for successful nursery establishment and seedling production*

Before initiating production schedules, a manager must obtain all equipment, materials, and supplies needed to produce the desired number of seedlings (*3*, *4*, *8*). Managers work closely with all groups requesting seedlings, including private industries, government agencies, and individuals. Maintaining good working relationships with nursery personnel is essential to smooth and efficient execution of production schedules.

Each step in a production schedule is identified, then listed in sequential order. Major production steps are then divided into minor ones. Breaking down the operational process into individual steps allows a manager to prepare lists for needed equipment, materials, and supplies. A good diagram will reveal potential problems in the production process, or it might indicate that more than one piece of equipment (e.g., two soil mixers) are more efficient than one piece for a particular operation. Individual steps in the production process can be translated to a standard work unit, for example 1,000 seedlings per man/hour. All nursery operations should be constantly under review for potential improvement (*1*, *2*).

To make realistic production schedules, nursery managers must know how and where to use each piece of equipment or procedure. They must be able to make adjustments and repairs or know where and how soon repairs can be made. Usually, they introduce new techniques and ideas and train supervisors to use them. Also, managers must 1) make sure laborers use equipment properly, efficiently, and safely and 2) stay abreast of new techniques and developments by reading nursery publications, visiting other nurseries, and attending nursery conventions on a regular basis.

Innovative nursery managers must not be content to let local traditions and labor habits dictate seedling production methods. If this happens, an entire program may be adversely affected. Periodic changes are often required that might upset work habits and traditions (*7*). To minimize conflicts with personnel and traditions, managers must educate their employees about the reason for and benefits of any changes.

Managers should also be cognizant of special community needs and realities. For example, although a semi-mechanized container operation may produce more seedlings in a shorter time than a less automated, more labor intensive operation, the latter may eventually be chosen. Such a decision would reflect long-term reforestation as well as socioeconomic program needs to utilize unemployed local labor (*5*). Employing local laborers promotes community self-help and fosters grass roots acceptance of nursery and reforestation objectives (*9*, *10*).

5.2 Some Specific Principles

5.2.1 Overall Planning and Coordination.—Coordination is required so that managers do not produce seedlings at the wrong time of the year. For example, if normal planting lasts from the beginning of
rainy season until 1 month before the rainy se
ends, seeds must be sown to produce seedl
throughout the entire planting season. If a forest
charge of planting needs 1 million seedlings
specific species, height, and age between Augu
and December 1, the nursery manager must trans
this information to a production basis. A certain
centage of each nursery crop contains cull seedl
that do not meet outplant specifications. Generall
least 10 percent more seedlings are produced thar
requested to allow for cull seedlings. The actual
factor is determined by careful observation over
eral years.

5.2.2 Disease.—Disease may also eliminate
seedlings, requiring an even greater margin of sa
The possibility of diseases killing a high percenta
all seedlings is a constant threat in any nurser
seedlings are produced on a staggered basis,
threat of total crop loss from a single disease is r
mized. Reducing losses from disease is crucial in a
where entomologists and pathologists are locally
available.

5.2.3 Seedling Growth Rates.—Managers rely
marily on experience to determine how fast seed
grow. For example, in some nurseries it may be p
ble to produce *P. caribaea* seedlings 25-30 cm ta
tween November 1 and May 1 (i.e., in only 5
months). However, if seeds are sown in Decemb
may take 6 to 7 months to produce the same
seedlings. This time difference is caused by sl
seedling growth from February 1 to April 30, the
mal dry season in that nursery area. Produ
scheduling is therefore based on expected gr
rates determined by personal knowledge and pre
growth records.

5.3 A Case Example

In this section a nursery production system i
scribed in detail, with special emphasis on major
ational steps. Basic arithmetic calculations for c
mining amounts of potting medium, seeds, and
materials needed are given in Appendix 9. The e
ple is limited to production of *P. caribaea* seed
using soil, plastic bags, and hand labor.

This concept can be applied to other species, an
system described can be established in almost
area having adequate water supply and level ter
The system is easily modified to accommodate te
rary nurseries. In contrast, a highly mechanized
tainer production system is discussed in Chapte

For the plastic bag production system desc
here, assume that a nursery manager must pr
1 million pine seedlings and that the seedling
needed between August 1 and December 1, the
favorable planting dates in his area. For ade
lead time to order new supplies, actual seedlir
quests should be submitted at least 1 year befo

jected planting date. Under usual growing condi-
ins, *P. caribaea* seedlings are ready to outplant
onths after germination, when they are 25 to
m tall and have a root collar diameter of 5 mm. If
edlings are grown in large bags (>400 cc) with soil,
y can usually be held in a nursery for 2 to 3 addi-
al months without seriously affecting their out-
t survival and growth. When held longer than
onths, potted seedlings must be root-pruned before
planting to remove balled or entwined roots. Root
ning avoids potential problems of greater
dthrow and disease incidence, which are associ-
l with poor root form.

n experienced nursery manager knows that a
imum of 7 months is required to produce
table seedlings; this factor is taken into account
n making a production schedule. Ideally, the pro-
tion process is split into several manageable
ses, with subgoals of producing 200,000 healthy
llings for outplanting on five dates the following
r: August 1, September 1, October 1, November 1,
December 1. Staggered production avoids having
seedlings ready to outplant on the same date.
thermore, when seedling production is separated
distinct phases, there is less risk of seedling loss
disease like damping-off.

he manager's objective is to produce the quality
quantity of seedlings ordered on dates specified.
stated in Sections 5.2.1 and 5.2.2, extra seedlings
grown to replace cull seedlings and those killed by
ase. It is generally unwise to hold small or slow-
ving seedings for long periods. Accumulated evi-
e shows that small, unhealthy seedlings are genetically inferior to normal, vigorous seedlings and grow more slowly after outplanting. To obtain vigorous seedlings, use quality seeds selected from superior tree seed sources whenever possible or ordered from reputable seed suppliers.

A real problem with tree species in great demand is purchasing adequate quantities of seeds. One example is *P. caribaea* var. *hondurensis*, for which 1 kilogram of seed in 1986 cost up to $300, with improved seeds costing even more. Managers must make personal contacts with seed dealers to arrange for supplies well in advance of anticipated sowing and production runs. Once seeds arrive, managers must decide if and how they should be stored, when they are to be planted, and in what proportions (*6*). Sowing rates for a production run are estimated from replicated trials showing germination percentage for seed lots that will be sown. Remaining seeds are stored as described in Chapter 6.

The most difficult part of any production run remains after sowing: growing seedlings to term. Constant monitoring is needed to determine moisture and nutrition needs. Vigilance is required to prevent insects and diseases from destroying seedlings. Weeds must be controlled. Additional concerns are abnormal short-term climatic influences (droughts or abnormally rainy periods) that might affect seedling growth and disasters like fires or hurricanes. Against fires, the precautions mentioned in Chapter 12 should be followed regarding facility security. If a hurricane is imminent, containers should be moved to protected areas (fig. 5-2). If bare-root beds are sloped properly

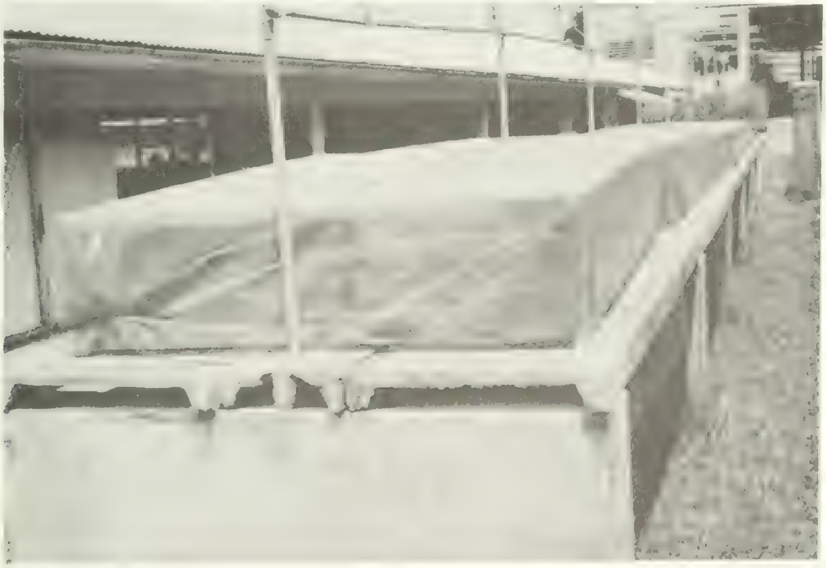


Figure 5-2.—*Storage space under raised cement benches can be used to temporarily store containerized seedlings during severe storms. Saran-covered box frames on benches protect newly-sown seed in germination trays from birds; using close-mesh metal screening instead of saran will protect trays against rats and mice.*

and soils are well drained, bare-root stock will survive all but the severest storms.

Once seedlings make it to term, they must still be lifted, packed, and transported to the field. Improper procedures in any of these later stages can cause undue mortality and reduce seedling vigor or health. As with all preceding production stages, only foresight and careful planning will avoid potential problems such as lack of packing materials and pallets, transport vehicles, or proposed vacation schedules for drivers and workers who must be present for the packing and transporting phases.

Skilled managers review all production phases carefully, well in advance of each production run. If planning is executed rigorously and if nursery managers are observant of daily changes in natural and work environments, each production run, large or small, should be successful.

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CHAPTER 6

6. SEED PROCESSING AND STORAGE

Seeds bought on consignment are already extracted and cleaned but must be stored properly. However, when fresh seeds are collected from local sources they must by properly cleaned and prepared for either short- or long-term storage. This chapter reviews the fundamentals of seed processing and seed storage. More detailed information on these topics and other seed harvesting and transporting techniques is found in USDA Forest Service Agricultural Handbook 450 (*17*).

6.1 Fruit Types and Processing Practices

Seed processing includes drying and initial extraction, cleaning, culling damaged or empty seeds, reducing and maintaining proper moisture content, and, if needed, applying protective treatments like fungicides (*2, 16*). Processing techniques vary slightly for the major fruit types: cones (pines), fleshy fruits (kadam and teak), and dry fruits (mahogany and *Cordia* sp.) The goal in processing each of these fruit types is maximum production of clean, viable seeds.

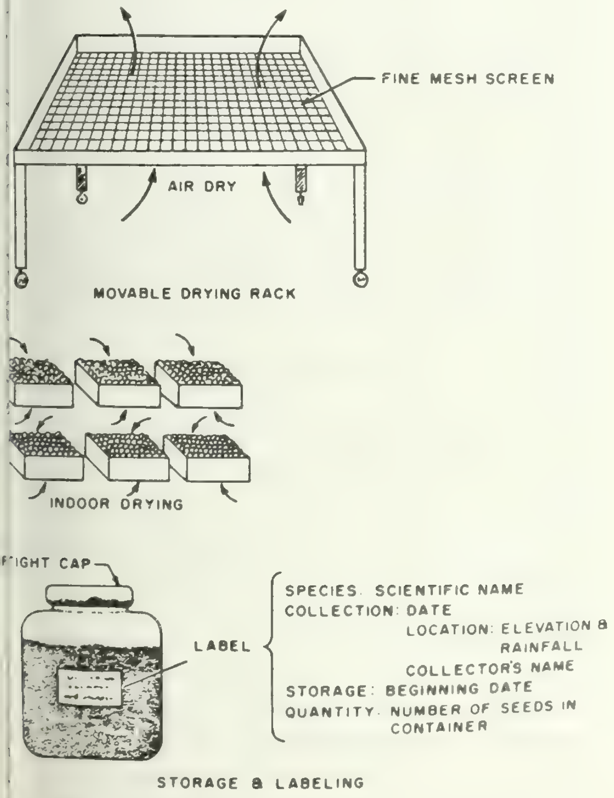
Of these seed processing practices, the most important is obtaining proper moisture content. Excess moisture can cause mold on seeds in storage. Mold is the most serious threat to seed viability. Therefore, several seed drying techniques are discussed. Other practices also important when processing seed include cleaning, maintenance, and adjustment of extraction equipment; preventing accumulation of flammable dust, resin, or debris; following safety guidelines; and using approved safety devices whenever required (e.g., use of dust masks when separating seeds from dirt and chaff).

6.2 Cones and Dry Fruits

6.2.1 Initial Inspection and Handling.—Newly collected seeds must be carefully checked for disease, insects, mold, and external moisture or dampness (which could cause mold at a later stage). Using plastic bags for seed storage and transportation is unsatisfactory because impermeable plastic traps condense isture inside bags. Green cones, pods, and dry its usually contain lots of moisture (*14*). Conse- ntly, heat buildup will occur inside the bags hough cellular respiration, and mold can then de- op because of the humid, warm, and dark condi- ns in tightly packed bags. Thus, excess moisture st be removed immediately after seeds arrive in nursery. Permeable paper, cloth bags, and cleaned lap bags are best for collecting seeds; they are ap and avoid moisture buildup, particularly when ds are packed loosely in them.

.2.2 ***Air-Drying.***—Most damp seeds, cones, or s can be air-dried. They are placed on protected ing screens or trays that allow sunlight and air to s through but keep out rain. Cheap and effective ers use elevated racks, allowing air circulation m below (fig. 6-1). The same design principle is d for simple, portable seed drying racks or large ing sheds.

rying screens and racks are basic seed processing ipment. Because most seeds lose germination or in processing, drying of external or surface isture is done as quickly as possible. Seeds should er be left for long periods in drying racks. Even at bient temperature, drying seeds will lose viability. ds are normally exposed to full sunlight for only 2 3 days. For uniform drying, seeds are evenly spread r the screens. A thin layer of seeds dries more quickly than a thick layer. Seeds are stirred or turned over 2 to 3 times each day, allowing exposure of the entire seedcoat to the sun's rays. Air-drying is basically a quick way to remove external seed moisture; it prepares seeds for sizing, dewinging, cleaning, and separating filled from empty seeds (Appendix 6).



ure 6-1.—*Seed drying and storage procedures. Adapted from (21).*

Processing large cone crops requires similar drying precautions. Sacked cones bundled too tightly cannot open fully and will obtain a "set" that precludes seed extraction (*3*). Packing sacks too close together stops adequate ventilation, causing heating and molding.

When small quantities of seeds are dried outside, on the ground or on paved driveways, one must be able to cover them quickly or move them inside when it rains. Similarly, seeds must be covered during the evening hours to avoid dewfall accumulation. A drying rack with wheels is easily moved to sheltered areas (fig. 6-1). All seeds must be screened from rodents and birds during drying.

6.2.3 ***Kiln-Drying.***—Large quantities of seeds, cones, or pods are usually kiln-dried. Kilns have many sizes and shapes. Two general types are the rotating-drum kiln and the large conveyor-belt, progressive-type kiln. Drum kilns are fairly efficient because their rotating or tumbling action also separates seeds from pods or cones. For small seed batches, a small rotating-drum kiln is probably the best purchase. Seeds are removed from inside the drum as soon as possible because excessive tumbling is harmful.

Most large kilns are heated by natural gas or electricity. The kind of fuel used has no influence on drying; the least expensive or most readily available fuel is used. Large kilns have automatic controls that graduate and maintain specific heat and humidity levels. If kilns have sensitive controls, cones are opened and seed moisture content is lowered sufficiently for long-term cold storage. When kiln-drying cannot reduce seed moisture content sufficiently, seeds are dried further in convection ovens.

Kiln temperatures should not exceed 54°C for pines. Mahogany and cedar pods are forced open by kiln drying at 43°C. Kilns are readily constructed from local materials. The major task is providing adequate air circulation and maintaining an even flow of uniformly distributed heated air throughout the chamber. Drawings of custom made kilns are available upon request (*8*).

6.2.4 ***Solar Dryers.***—Solar dryers are used for extracting seeds in the tropics, where the number of days with full sunlight is high. An experimental solar dryer at ITF (fig. 6-2) is rountinely used to open mahogany pods, cedar pods, and pine cones and to dry seeds of various species. Under normal sunlight conditions, pods and cones open within 3 to 4 days. Failure to stagger cone collecting over normal field maturation results in an accumulation of large quantities of cones that cannot be dried immediately because of a

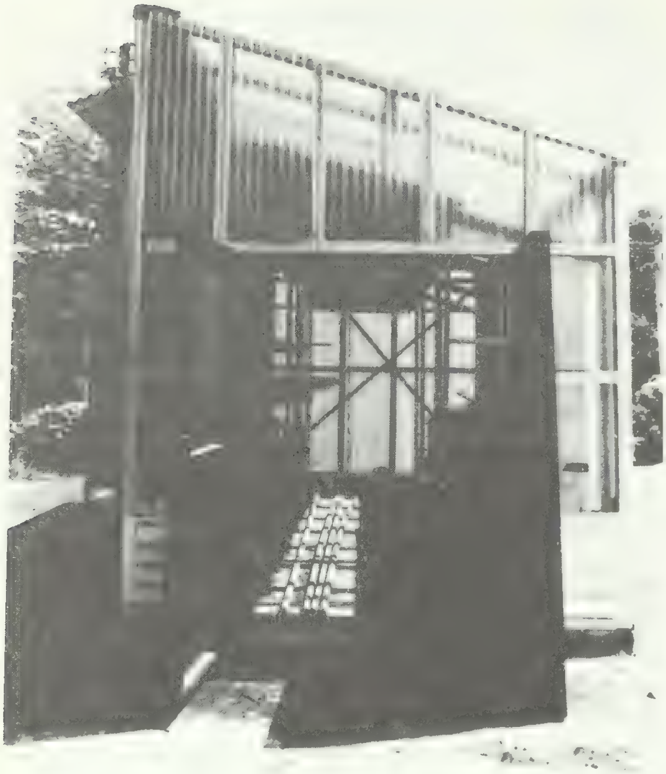


Figure 6-2.—*Solar dryers are effective for drying seeds as well as lumber. Many designs exist; they are easy to construct and require little maintenance. The one shown here has fiberglass side and roof panels covering a treated wood frame.*

lack of space. If cones are improperly stored while awaiting drying, they may mold.

Extraction may be done with a power-driven tumbler inside a solar dryer. Because solar dryers operate mostly on radiant energy, the only cost involved, besides labor, is the small amount of electricity used by a small motor that turns the tumbler and runs an extractor fan that blows moist air from the dryer. Solar dryers are simple to build; a wide variety of designs exists (*13, 15*). A clever carpenter can easily build a solar dryer, making special design adaptations for local conditions.

Because of design constraints, sensitivity control of humidity and temperature on solar dryers is not as precise as that on manufactured kilns or ovens. Moreover, heat buildup inside a solar dryer can fluctuate more than what normally occurs in ovens or kilns. Thus, solar dryers are not routinely used for lowering seed moisture content.

Another problem that might occur is rupture of the solar dryer. This is caused by expanding cones that occupy greater physical volume when expanded than when closed. There have been cases where walls of drying buildings have been pushed out or roofs lifted off as pine cones dried and expanded. Thus, one should always leave sufficient room in large or small solar dryers (about 50 percent of structure volume) for cone expansion.

6.3 Fleshy Fruits

Seeds with fleshy coverings require different p essing than that required by cones and dry fruits (The kind of processing depends on whether seeds a covered by thin or thick flesh. If fleshy fruits are processed soon after they are collected, fermenta and spoilage occur because high moisture and su content of the flesh favor bacterial and yeast grow

Flesh is removed by hand or machine meth Kind, quality, and value of the fruit determine wh method is used. Small seed lots are usually macera by hand: by squeezing, mashing, or rubbing fr against wooden blocks or screens. Using nested sie held under running water allows pulp to be was away while retaining seeds.

Heavier seeds of fleshy fruits are separated by fl tion. Macerated debris and seeds are placed i slightly tilted bucket. A strong stream of runn water from a garden hose is then directed against container side, creating a swirling and lifting eff Empty seeds, pulp, and other debris float to the face and exit in overflow water. Good seeds are he ier; they sink and are trapped in the container.

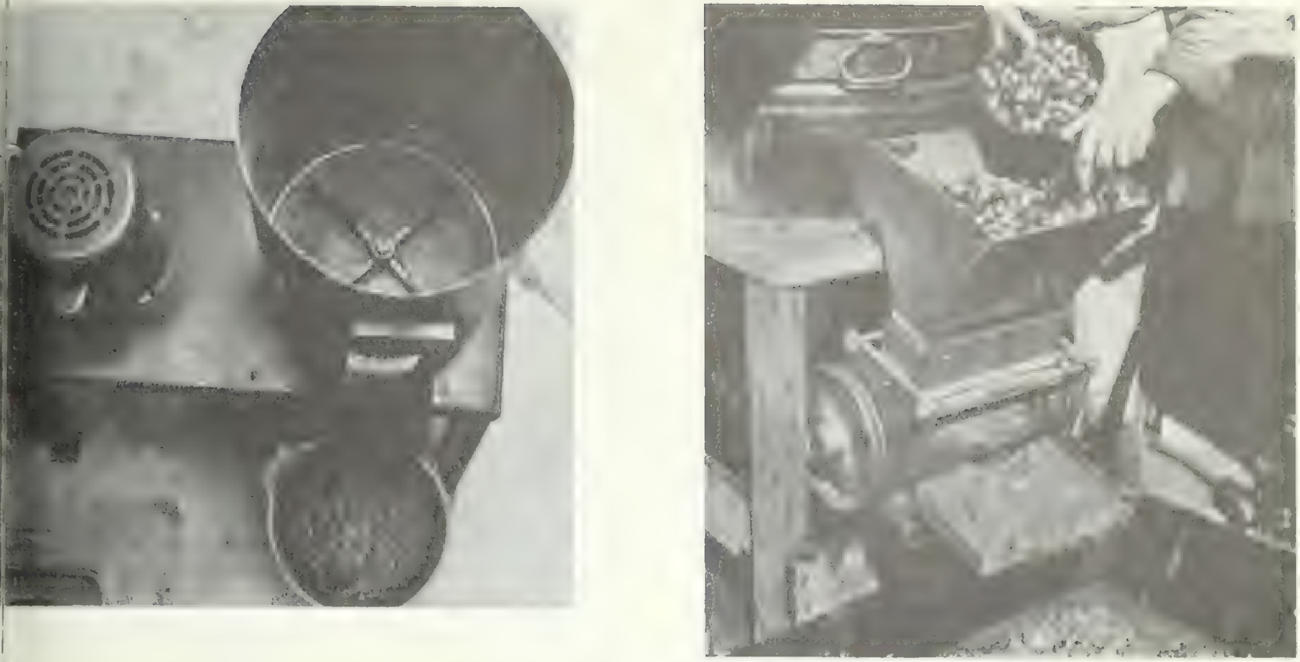
Large seed lots are best processed using f grinders, concrete mixers, or commercial macera and separators (fig. 6-3). Some machines free flesh from the seed, leaving seeds and residues t are separated in a later cleaning. Other equipm separates pulp from seeds and cleans seeds in a sin operation. A flotation procedure is used to sepa seeds from pulp and debris, as explained above. T fleshed seeds like teak require no macerating, drying after initial cleaning and washing.

After fruits are macerated and seeds are separa and washed, seed surfaces must be dried. This ca done indoors or outdoors on any clean surface tha sheltered. In moist climates where air-drying is sufficient, kilns or ovens are used. Final cleaning separating is done using air-screens or air-colu (fig. 6-4) to remove chaff and light debris (*18, 19*

6.4 Moisture Content Considerations

Kind of seeds, maturity, presence of fungi or ba ria, and prestorage treatment all influence longe and viability of stored seeds. In general, optimum ditions for maintaining high seed viability over l periods are a combination of low seed moisture tent and low ambient temperature during storage *11, 12*).

High seed moisture content causes several p lems. At 30-percent moisture content or above, se may germinate if the storage temperature is too h If moisture content of stored seeds is between 15 30 percent, germination is improbable, but cell respiration of stored nutrients in the endosperm ers seed viability. Reducing seed moisture conten between 10 and 12 percent effectively eliminates r



igure 6-3.—*Separating large seeds from fleshy fruits.*

f these problems. However, fungi can still survive in his moisture content range, and molds can develop. nsects will even attack seeds when moisture contents re as low as 8 to 9 percent if they are stored above freezing temperatures.

In areas without refrigerated storage, seeds are ften stored at ambient temperatures of 20° to 35°C. When seeds stored at higher temperatures are chemially treated to avoid insect and disease attack, internal moisture content will equilibrate at 8 percent if torage room relative humidity is maintained at 40 percent and room temperature is <13°C. If relative humidity is 60 percent and storage room temperature is 7°C, seed moisture content will eventually equilibrate to 12 percent. Wakeley (*20*) developed a chart for determining equilibrium of seed moisture content of longleaf pine in relation to temperature and relative humidity of a seed storage area (fig. 6-5).

The most accurate way to determine seed moisture is the oven-drying method of the International Seed Testing Association (*7*). Oven-drying measurement of moisture content is explained in Chapter 7. If moisture content is too high (≥ 12 percent), seeds should be dried at 55°C, following instructions and precautions outlined in Chapter 7. Electronic moisture detectors determine seed moisture content with sufficient accuracy to permit their use in seed laboratories.

6.5 Cleaning and Storage

Because cold storage is costly and uses space, separating empty from full seeds before storage is essential in seed processing. Several methods exist that separate seeds by endosperm content. Mechanical separation, involving a vibrating table held at a slant, is the most common method. Another method uses an air stream in baffled tubes (fig. 6-4). Percentage of full and empty seeds is estimated by sampling techniques using a low number of seeds. Flotation can be used to separate empty seeds (*12*), but moistened full seeds must be dried to stop mold development. In one instance, fire was used to separate balsa seeds from surrounding down-like material (*5*).

If seeds are sown shortly after collection, they can be stored temporarily at normal refrigerator temperatures of 2° to 3°C. Seeds of *P. caribaea* store fairly well in refrigerators if moisture content is less than 12 percent. Refrigerated seeds lose approximately 1.5 to 2.5 percent germination capacity per month. If storage is longer than 4 months, moisture content should be lowered to < 10 percent and the seeds should be frozen. Seeds of kadam and *Eucalyptus deglupta* store slightly better, with a germination loss of less than 1 percent per month. Because mahogany seeds lose viability quickly, even if refrigerated, they should be sown within 1 month of collection.

Seeds refrigerator-stored in sealed containers should not be removed unnecessarily. Condensation of moisture on inside container walls helps mold development. If seed subsamples must be removed from time to time, seeds should be stored in smaller packages, allowing minimal exposure to moisture.

Routine long-term storage of 5 to 10 years for many tree and shrub species, especially pines, is obtained by

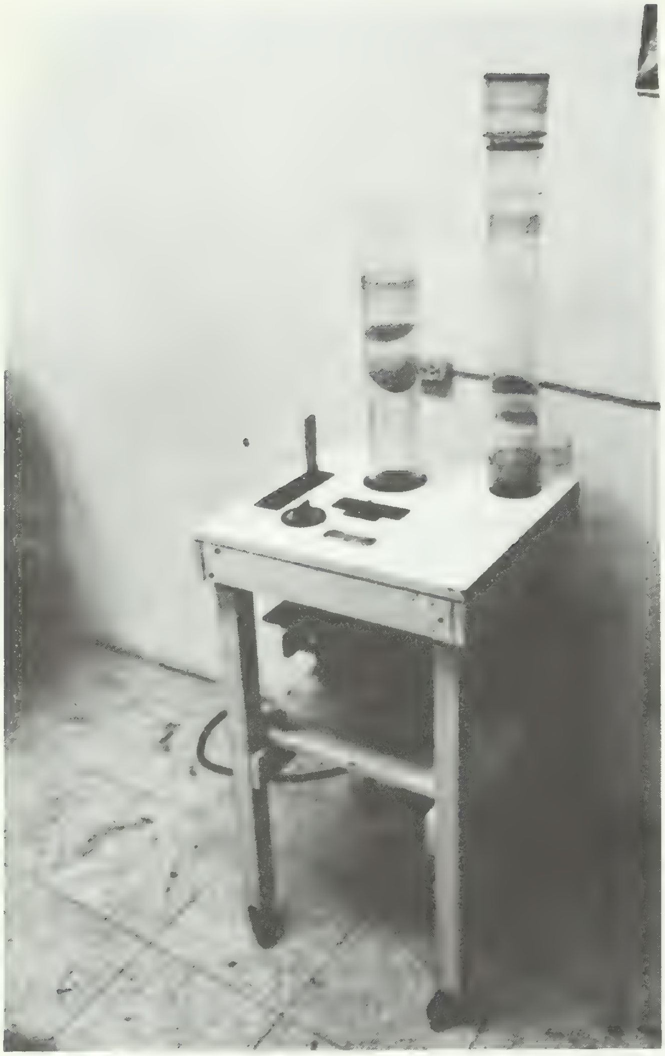


Figure 6-4.—*Mechanical separation of full and empty seeds by baffle-tube, air-column technique.*

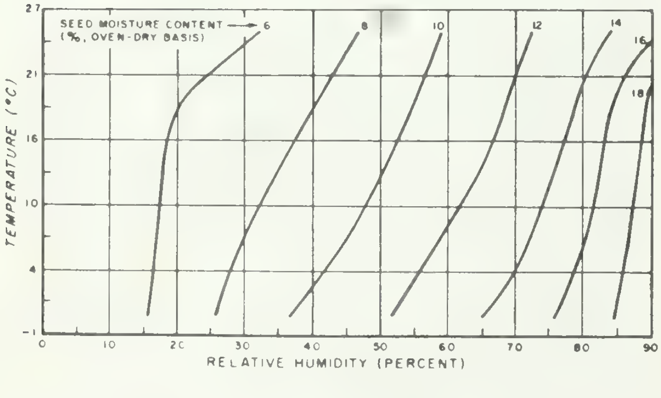


Figure 6-5.—*Chart for determining equilibrium of seed moisture content of longleaf pine when temperature and relative humidity of seed storage area are known. Taken from (20).*

freezing at 0°C or lower temperatures, with seed is-
ture content between 5 and 10 percent. Long- m
storage is important for storing genetically supe or,
scarce pine provenance seeds and for storing bu er
seed crops. Dry tree seeds have tolerated extre ly
cold temperatures of −200°C (*4*); however, such ow
temperatures are not practical for long-term sto ge.
More specialized methods, including storage u er
partial vacuum (*1*), storage in an inert gas suc as
nitrogen (*9*), and replacing oxygen with carbon x-
ide in storage containers (*6*), have had variou le-
grees of success with certain species. Such met ds
are not practical for most seed storage operations, ar-
ticularly in most developing countries.

Choice of containers for seed storage depend on
whether storage is short or long-term. For the la er,
rigid-walled containers (e.g., glass) that restric air
and moisture entry are preferred. These, design ed
as "tightly closed," are seldom completely airtig or
sealed, i.e., completely impermeable to entry o air
and moisture (fig. 6-1).

When needed, internal moisture content can be n-
trolled by using silica gel, charcoal, or chemical u-
tions, as long as these have no adverse effect on ne
seeds. For short-term storage, plastic bags are ch p,
effective alternatives. If tied properly, they exc de
moisture but allow exchanges of oxygen and ca on
dioxide with outside air. Remember, however, at
plastic bags are *not used* for seed collection ec.
6.2.1).

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CHAPTER 7

7. SEED TESTING

Several tests assess the physical and biological aspects of seeds (*14*). Test results help determine price if seeds are sold, indicate the number of seeds to sow per unit area of nursery for a production run, and evaluate available seed stocks for reforestation programs. Many tests are now standardized internationally, allowing better communication among nursery managers, foresters, and scientists working with seeds.

Seed tests are commonly done immediately following extraction and shortly before actual sowing. Some tests are done periodically on seed lots kept in long-term storage. Only brief summaries of the more common tests are given; detailed descriptions of tests and seed testing problems appear elsewhere (*8*, *10*, *15*).

7.1 Sampling

A single seed lot can be large or small; it may fill an entire cold storage room or one small bag. To guarantee reliability of seed test results for large lots, all tests must be run on representative samples of the entire lot. Seed triers (fig. 7-1) draw seed samples from large bags or boxes. Electrical sample dividers then split the sample into two or more subsamples on which purity or germination tests are run. For small nurseries, common sense, clean hands, a clean workbench, and a large-bladed knife are sufficient for most seed testing tasks.

Required sample sizes vary according to number and kind of tests run. For germination, at least 600 seeds are needed; a complete seed analysis requires at least 2,500 seeds. Minimum working sample sizes for tree seeds are given in table 7-1. If low viability or a large amount of empty seeds are suspected, then minimum sample sizes (weights) should be double or perhaps triple those listed in table 7-1.

If seeds are stored in large boxes or crates, hand samples are taken at the top, center, bottom, and sides of the box. Samples are taken in proportion to size of the box or container. One should take twice the amount of seeds from a 0.5-m^3 box than from a 0.25-m^3 box. When seeds are stored in small bags, mix them thoroughly before sampling. For small lots of 1 to 6 bags, sample each; for more than 6 bags, the rule of thumb is to sample 10 percent of the total number of bags plus 5 (*15*), as shown below.

Number of bags in seed lot	Number of bags to be sampled
8	6
10	6
20	7
35	9
50	10
100	15

For a lot size of 8 bags, 10 percent of 8 is 0.8 or 1 when rounded off; then 1 + 5 = 6 bags to be sampled.

7.2 Weight

Accurate seed weight is necessary to calculate nursery sowing rates. Weight is normally expressed for 1,000 full seeds. Factors affecting seed weight are size, moisture content, and proportion of full seeds in the lot. One can count out and weigh 1,000 seeds, or, as is done more routinely, 10 random samples of 100 seeds each are taken from a pure batch and weighed (*8*). For commercial testing, weights are recorded to three significant digits; for small nurseries, one significant digit is enough. Besides the mean seed weight in grams, other useful data include the standard deviation, standard error, and coefficient of variation of the seed samples (Chap. 14).

To convert the weight of 1,000 seeds in grams to number of seeds per pound:

$$\frac{453{,}600}{\text{weight of 1,000 seeds in grams}} = \text{number of seeds per pound;}$$

similarly,

$$\text{number of seeds per gram} = \frac{\text{reported 1,000 seed weight in grams}}{1{,}000}$$

7.3 Purity Analysis

Purity tests determine the percentage of true seeds and other material in a seed lot. The four recognized components are pure seed, other seeds, weed seeds, and inert matter such as seed wings, broken cone scales, rocks, twigs, or other non-seed material. Co mercial germination tests use the pure seed com nent only. Each component is usually expressed percentage by weight of the original sample. Thus the initial weight of a *P. caribaea* seed sample v 60.124 g and the pure portion weighed 52.467 g, rity of the lot is:

$$\frac{52.467}{60.124} \times 100 = 87.3 \text{ percent.}$$

Purity tests are meticulous, slow operations. Se ration is done best by working on a board or rai platform about 8 to 15 cm above normal table heig A multiple-tube daylight fluorescent light is be Other required equipment are forceps and spatula seed handling and separating, a wide-field hand le of 5 to 7× power, a wide-field stereomicroscope w magnification from 10 to 75×, seed pans, and a b ance. Analytical balances that weigh to three or f significant digits are used in international seed te ing labs. Tortion-bar and other balances that weigh only one significant digit are suitable for small nu eries.

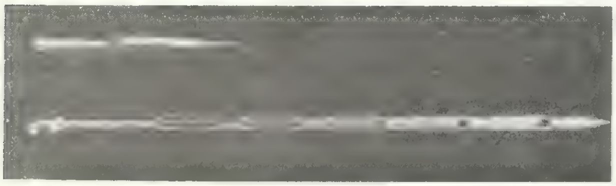


Figure 7-1.—*Seed triers for obtaining representative seed samples for germination tests. With slots open, triers are inserted into seed lots; when slots are closed, seeds are trapped and can be used for seed testing after trier is removed.*

Table 7-1.—*Minimum sample sizes for seed testing*[1]

Seeds per kilogram	Minimum working sample size	Seeds per gram
Number	*Grams*	*Numbe*
less than 4,400[2]	500[3]	less than 5
4,400-5,500	300-400	5-
5,500-6,600	200-300	7-
6,600-7,700	140-240	10-
7,700-8,800	100-170	15-
8,800-9,900	85-125	20-
9,900-11,000	70-100	25-
11,000-12,000	60-90	30-
12,000-13,000	54-75	35-
13,000-15,000	42-65	40-
15,000-18,000	36-54	50-
18,000-20,000	30-46	60-
20,000-22,000	27-40	70-
22,000-23,000	24-35	80-
33,000-44,000	22-32	90-
44,000-55,000	17-28	100-
55,000-66,000	15-23	125-
66,000-88,000	13-20	150-
88,000-110,000	11-17	175-
110,000-143,000	9-15	200-
143,000-176,000	8-12	250-
176,000-220,000	6.5-10	300-
220,000-331,000	5.5-8.5	350-
331,000-441,000	4.4-7.5	400-
441,000-661,000	3-6	500-
more than 661,000	3	more than

[1] Source: Association of Official Seed Analysts 1970.

[2] Purity analyses are rarely required for seed samples of this s

[3] Sample should contain at least 500 seeds.

Separation is done manually by placing about 400 seeds on the working board or bench, drawing a few seeds at a time from the main pile, spreading them apart, and finally determining into which component tray or pan the material should be placed. After preliminary separation is made, all components are rechecked.

Imperfect seeds of the same species being checked are not classified as other seeds or inert matter. However, immature, shriveled, cracked, and damaged seeds larger than one-half the original seed size, including those with internal insect damage and those starting to germinate, are designated as "pure" seed. This may seem strange, but germination potential is determined by a germination test, not a purity test.

7 Moisture Content

Seed moisture content has an inverse relationship with seed longevity and germination capacity: at high seed moisture (≥18 percent), seed germination capacity and longevity are lower. Managers check seed moisture content soon after receiving fresh seeds or seeds that have been in transit a week or more. Also, periodic checking every 6 months is essential for monitoring viability of seed lots kept in long-term storage (2).

The common laboratory test for determining seed moisture content is the air-oven method developed by the International Seed Testing Association (*8*). It is prescribed for all tree and shrub seeds except those from fir (*Abies*), cedar (*Cedrus*), beech (*Fagus*), spruce (*Picea*), and hemlock (*Tsuga*). Seed from these genera contain oils and resins that are volatile at 15°C.

In the air-oven technique, a representative seed sample is weighed to three decimal places, dried at 13° ± 2°C for 17 ± 1 hour, and reweighed after cooling in a desiccator for 30 to 45 minutes. Percent moisture (i.e., seed moisture content) is obtained by dividing the weight of water lost in drying by the *wet weight* or weight before drying. Duplicate determinations are run on the same seed lot being tested. If results differ by >0.2 percent, another duplicate determination is made, following the same procedures.

For example, assume that wet weights of duplicate samples A and B are 20.197 and 20.186 g. After 17 hours, dry weights for A and B are 18.062 and 18.002 respectively. Seed moisture contents are:

$$\text{A:} = \frac{20.197 - 18.062}{20.197} \times 100 = 10.6 \text{ percent, and}$$

$$\text{B:} \quad \frac{20.186 - 18.002}{20.186} \times 100 = 10.8 \text{ percent.}$$

Since the difference in moisture contents between A and B was 0.2 percent, no retest is needed.

If seed moisture contents are known to exceed 17 percent, seed subsamples are weighed, predried at 55°C for 5 to 10 minutes, reweighed after cooling, and then run through the normal air-oven technique. Percentage of moisture is determined by dividing the weight of water lost from the two drying periods by initial wet weight.

For example, assume that initial wet weight of a seed sample is 26.000 g and that an electronic seed moisture meter showed a seed moisture content of 32 percent. To check this, the seed sample is dried at 55°C for 10 minutes. The resulting weight (W) of 20.197 is an initial loss of 5.803 g (W_1). After drying for 17 hours at 103°C, the second weight is 18.062 g, an additional loss of 2.135 g (W_2).

Actual seed moisture content for the sample is:

$$\frac{\text{Weight loss W1 + W2}}{\text{inital wet weight}} \times 100, \text{ or}$$

$$\frac{5.803 + 2.135}{26.000} \times 100 = 30.5 \text{ percent.}$$

When reporting results, one must always specifiy whether percentage of moisture was obtained by dividing by wet or dry weight. In the United States, seed *moisture* content is usually expressed as a percentage of *oven dry weight* after the 17-hour drying. This procedure differs from international custom where expression on a *wet weight basis* is almost always used. Conversion from a wet to dry weight basis is done easily by using the scale shown in figure 7-2.

In commercial seed testing, the toluene distillation method replaces the air-oven method for determining seed moisture content of species having resins or other materials that volatilize at 105°C. The method involves grinding seeds finely, boiling them in a toluene apparatus, collecting condensed moisture in a separate tube, and determining moisture content of the seeds by using their initial weight and weight (or volumes) of water collected in the distillation apparatus. Most nurseries do not have access to such specialized equipment. Therefore, oven drying at 103°C for 17 ± 1 hour is satisfactory for determining seed moisture content of most species.

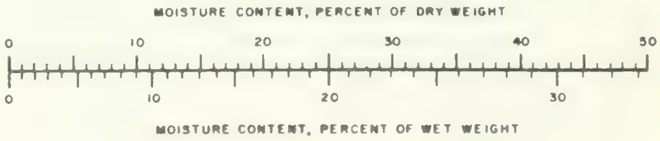


Figure 7-2 —*Conversion from wet to dry weight basis when determining seed moisture content. Taken from (15).*

7.5 Germination Potential

Germination potential is determined from the pure seed component of purity tests. Alcohol is sometimes used to separate viable from nonviable seeds (*6*). When pure seeds are not available, representative samples of lots should be tested as long as estimated purity is ≥98 percent (*1*). Results from germination tests help determine value of the seed lot, whether it should be used in the current planting season, if it can be stored for future years, and what sowing rates must be used in nursery beds to meet established seedling production goals (*16*).

The science of germination testing is complex, covering such areas as equipment (cabinets, rooms, or trays and dishes), suitable medium (paper towels, sand, peat moss, etc.), procedures (moisture, light, and temperature regimens), and (evaluation classifying normal and abnormal seedlings). Once germination test results are judged satisfactory for a particular species, techniques and methodology should be standardized and continued in all future germination tests. When tests are standardized and routine, direct correlations between seed testing results and seedling field performance can be made by nursery and field managers for specific locations and circumstances.

7.5.1 Germination Test Procedures.—In any germination test, seeds must be thoroughly mixed and representative samples drawn randomly by hand or with seed triers (fig. 7-1). Replicated tests are run using at least 600 seeds in 6 replicates. If 100 seeds do not fit in test trays, smaller replicates of 50 or 25 seeds are used. The mean germination rate (expressed in percent) for all replicates is used to calculate the number of seeds needed for actual sowing (Appendix 9). Some seeds require pretreating such as cold stratification or seedcoat scarification before germination (Chap. 8) or require certain temperatures for best germination (*3*).

Some germination tests are still done outdoors in flats containing sand, peat, vermiculite, or soil. Although such test conditions are good for large-seeded species such as teak, control of moisture and temperature cannot be maintained for outdoor tests. Outdoor tests have added risks of damage or loss of seeds by birds, rodents, or insects.

Indoor germination tests are conveniently run in small or large petri dishes or other trays; homemade cabinet germinators are also used (*4*). These should be sterilized before a test is started. Common substrata are moistened filter paper, paper towelling, blotters, or commercial paper tissues such as Kimpak. Paper substrata are nontoxic to germinating seedlings, free of molds and other harmful micro-organisms, and provide adequate moisture and aeration. Paper substrata can favor fungi if too much water is added, i.e., when water is seen collecting around seeds in the tray or if a film of water forms on fingers after squeezing paper. Fungi are controlled by spacing seeds wid and by removing seeds after they are fully ger nated. If substrata such as washed sand or perlite used for large seeds, seeds are covered loosely with material, usually to a depth equal to one-half th diameter.

In the tropics, the indoor and outdoor temperatu range between 20°C and 30°C, which are suitable germinating most forest seeds (*2*). Germination te should not be done in poorly ventilated buildi where temperatures exceed 30°C or in air-conditio offices cooled to ≤20°C. One exception is teak see which require alternating temperatures of 35°C 38°C for successful germination (*11*). Covering ger nating trays maintains adequate humidity and mo ture. Seeds exposed to very high humidity and te perature before testing will have low germinati invalidating test comparisons (7). Another excepti is *Pinus ayacahuite*. Recommended germination fo is 25°C for 44 days or for 28 days after removing 3 4 mm of the seedcoat from the radicle end of seed

7.5.2 Seedling Evaluation.—Germination is t emergence and development from the seed embryo all essential structures, showing a seed's capacity produce a normal, healthy plant under favora growing conditions. Abnormally germinat seedlings do not count as "being germinated." Th may, however, be counted and placed in abnorm germination classes such as weak, rootless, or brok seedlings; albino or translucent seedlings; a stunted or malformed radicles. Seedlings with fung or bacterial damage can be counted as "germinated' they are otherwise normal.

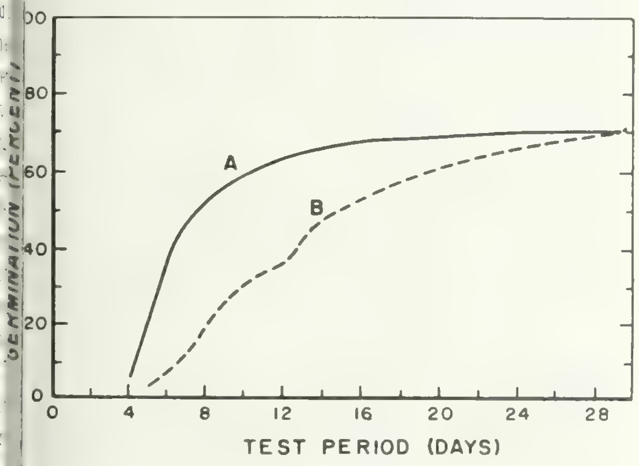
Test durations vary according to species and se size within species (*5*). At one extreme, teak seeds c take up to 1 year or longer; for other species, 3 to weeks are usually sufficient. Counts should be ma every 2 or 3 days, or more often for rapidly germina ing seedlings.

Remaining ungerminated seeds are added to t total number germinated to give the percentage of f seed in the sample. If cutting tests reveal many f but ungerminated seeds, pretreatment technique germination environment should be changed. Rete ing is necessary when: 1) a large percentage of see remain ungerminated and 2) a variation among te replicates exceeds that judged acceptable by past e perience or tolerances commonly allowed (table 7- Cumulative germination curves can be prepared a kept to identify higher quality seed lots (fig. 7-3).

"Quick tests" for determining seed viability are al possible. The most common, but least reliable, is t cutting test. Seeds are cut or split with a knife, a only those having healthy, firm, and undamaged e dosperms are judged viable (*15*). Biochemical stai le 7.2.—*Germination tolerance among 4 or more replications of 100 seeds each*[1]

Mean germination	Tolerance variation among replications
---------- *Percent* ----------	
or over	5
or over but less than 96	6
or over but less than 90	7
or over but less than 80	8
or over but less than 70	9
s than 60	10

Source: (1).



ure 7-3.—*Typical cumulative germination curves for two seed lots of one tree species.*

ig, using tetrazolium (TZ) salts, or embryo excision tts require experienced technicians for performing aalysis and interpretations. Soft X-ray tests are even fater than staining tests and indicate insect or processing damage as well. Initial expense for X-ray units ad additional expenses in purchasing and developig film probably limit this technique for most tropic nurseries. The X-ray technique has been used successfully for teak (*9*).

7 Other Special Tests

Several other seed tests may have implications for prticular nursery operations.

7.6.1 Seed Vigor.—Vigor is a rather loose term ued to describe observable germination differences i seed lots of similar or different genetic makeup. For eample, seed lots A and B in figure 7-3 both showed cmulative 70-percent germination in 30 days. Lot A, hwever, achieved this percentage in only 14 days, een though both lots were of the same species and vre exposed to the same overall germination conditions. Other examples of vigor besides rapid germination are germination under adverse conditions, resistance to fungal or other diseases, and corresponding vigor carry-over to nursery and planted seedlings.

The most common expression of vigor for tree seeds includes assessing speed of germination, also known as germinative energy. This is defined as the percentage of germination at the peak rate of germination. Slow germinating lots (Lot B, fig. 7-3), are difficult to determine. A more common expression is total number of days required for a certain proportion of total germination to occur (e.g., 85 percent of *P. caribaea* var. *hondurensis* seeds in 14 days). Such definitions are possible from long-term observations or experience of nursery managers, but they are seldom published or quantified through repeated and replicated trials.

7.6.2 Indirect Indices of Seed Vigor.—Indirect indices of seed vigor include biochemical staining tests using tetrazolium. Several vigor classes can be developed, based on partial or complete staining of the embryo and location of dead or damaged tissue. A major problem is standardization of test results. A successful technique exists for eucalyptus (*13*). Other biochemical tests exist, but most require sophisticated techniques and controlled laboratory environment, which are seldom available to field nurseries.

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CHAPTER 8

8. SEED PRESOWING TREATMENTS

Presowing seed treatments (pretreatments) are needed to break seed dormancy resulting from either a hard seedcoat or an immature embryo. A classic example is teak seeds, with a hard seedcoat, which may not germinate for 2 or 3 years after sowing (*4*). Dormancy is beneficial for natural regeneratio species because it postpones germination until able growing conditions exist. But irregular layed germination is disastrous for nurseries, all seedlings must reach uniform outplanting si specific dates. The purpose of pretreating is to seed dormancy and to obtain uniform germinat

The ability of pretreatment methods to over dormancy varies greatly by species. In general, of species growing in warm and moist tropical do not need pretreatment (e.g., *P. caribaea*). How species from cool temperate and dry tropical with distinct seasons may need some sort of pret ment before uniform germination can occur *Pinus tropicalis* and *Albizzia falcata*). Some pret ment methods commonly used in nursery wor species planted in the tropics and subtropics are marized in Appendix 8. Sometimes, treatment chemicals does not break dormancy but enhance mination (*3*, *8*).

8.1 Breaking Seedcoat Dormancy

Seedcoat dormancy is corrected by breaking hard and impermeable coat surrounding seeds legumes and teak) by chemical or mechanical ods.

8.1.1 Acid Scarification.—A common chem method is scarification with commercial grade s ric (H_2SO_4) acid (*6*). Several safety precautions be followed when using the acid-soak method. include using acid resistant wire containers or sc for handling, draining, and washing seeds; prov a good source of running water; establishing a area to drain and dilute the acid obtained from ing; and finding an area to dry seeds after rinsi

Complete methodology and precautions are in Agricultural Handbook 450 (*7*). Determine th timum immersion time for individual species nee pretreatment. Some species require 15 to 60 mi of soaking, others require up to 6 hours. Imme time is determined by soaking several small see for different times in acid, followed by soaki water at room temperature for 1 to 5 days. The soak treatment that yields the highest percenta swollen seeds (caused by water uptake), without ting seeds or exposing their endosperm, is the treatment. If differences in seedcoat composition between lots, separate treatment times may b quired. Lots up to 100 kg are treated effectivel placing a wire screen filled with seeds inside a drum (fig. 8-1). Another alternative for thin-c seeds is to place them in a conical pile on a flat, surface, apply acid at a rate of 2.5 kg per 36 seeds, mix thoroughly with a shovel, rinse, an the treated seeds.

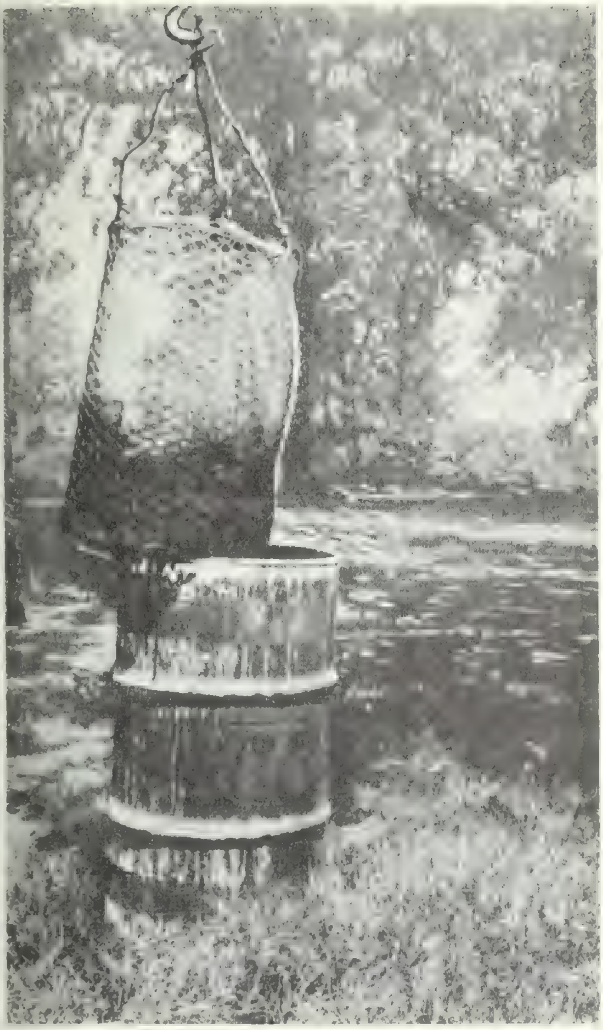

Figure 8-1.—*Acid pretreatment of large seed lots using wire screens and metal drums.*

Advantages of acid scarification are: 1) little or no ecial equipment, 2) low cost, and 3) recovery of acid r future pretreatment (unless the pile method is sed). Disadvantages are: 1) length of treatment must e carefully determined, 2) temperature must be con- olled, particularly when large lots are pretreated, nd 3) acids are hazardous substances.

When acid is used, *NEVER ADD OR SPLASH ATER ON ACID* because a violent reaction or ex- losion can occur!

8.1.2 Water Soaking.—Alternate soaking in hot nd cold water is the other major chemical method for retreating seeds. For large seeded species like teak nd legumes, success is achieved best with hot water. his method involves preheating water, 4 to 5 times e seed volume, to temperatures of 77°C to 100°C, bmerging the seeds, and allowing them to soak in e gradually cooling water for 12 to 24 hours. Some ecies have seeds that tolerate only a few minutes of ot water soaking (e.g., *Leucaena*); they must be uenched in cool water first before the long soak at room temperature begins. Problems arise in: 1) standardizing the technique, 2) maintaining precise control of times and temperatures, and 3) treating large seed lots.

Soaking in water at or near freezing temperature for a few days to 2 weeks has expedited germination of coniferous seeds; cold soaking is not successful for hard coated seeds on which acid scarification is used. Soaking probably leaches germination inhibitors from seeds, softens hard but not impermeable seedcoats, or completes an imbibition requirement for germination. For example, alternate-day soaking in water, and night drying for 7 days before sowing increased the germination percentage of *Terminalia ivorensis* from 30 percent to as much as 70 percent in Ghana (*1*). Germination period for *P. caribaea* was reduced by water-soaking seeds for 48 hours at room temperature (*5*).

8.2 Mechanical Scarification

Impermeable seedcoats can be broken mechanically with files, sandpaper, and electric needles for small lots and with hand or motor-driven scarifiers, such as sandpaper-lined drums and cement mixers, for large lots. Germination tests are needed, as for acid scarification, to determine optimum treating time. One verifies successful seed treatment by observing swelling after water uptake or visual examination with a hand lens. Overtreatment damages seeds by reducing germination and increasing risk of fungal attack.

Advantages of mechanical scarification are: 1) less risk of injury to workers, 2) no need to control temperature, and 3) seeds remain dry throughout pretreating, allowing immediate sowing afterwards. Disadvantages are: 1) seeds are easily damaged by overtreatment, 2) scarified seeds are perhaps more easily damaged by pathogens than are nonscarified seeds, 3) large lots require special equipment, and 4) seeds with resins or fleshy pulp cannot be used in sandpaper-lined tumblers.

8.3 Stratification Methods

Besides seedcoat or "external dormancy," some tree seeds have "internal dormancy." Before such seeds germinate they must undergo physiological changes in which the seed embryo develops. Cold, moist treatments that artificially cause these changes are called stratification; they are also known as moist prechilling or afterripening treatments.

8.3.1 Cold Stratification.—In cold stratification, seeds are stored in a well-aerated medium such as sphagnum moss and kept at low temperatures of 1° C to 4°C for 2 to 4 months. Three precautions that must be taken are: 1) maintain adequate moisture that can be imbibed by seeds throughout stratification; 2) keep temperatures low, near freezing, to reduce microbial activity, reduce sprouting, and prevent heat buildup from seed respiration; and 3) supply adequate aeration for gas and heat exchange, particularly for long-term stratification of 2 months and longer.

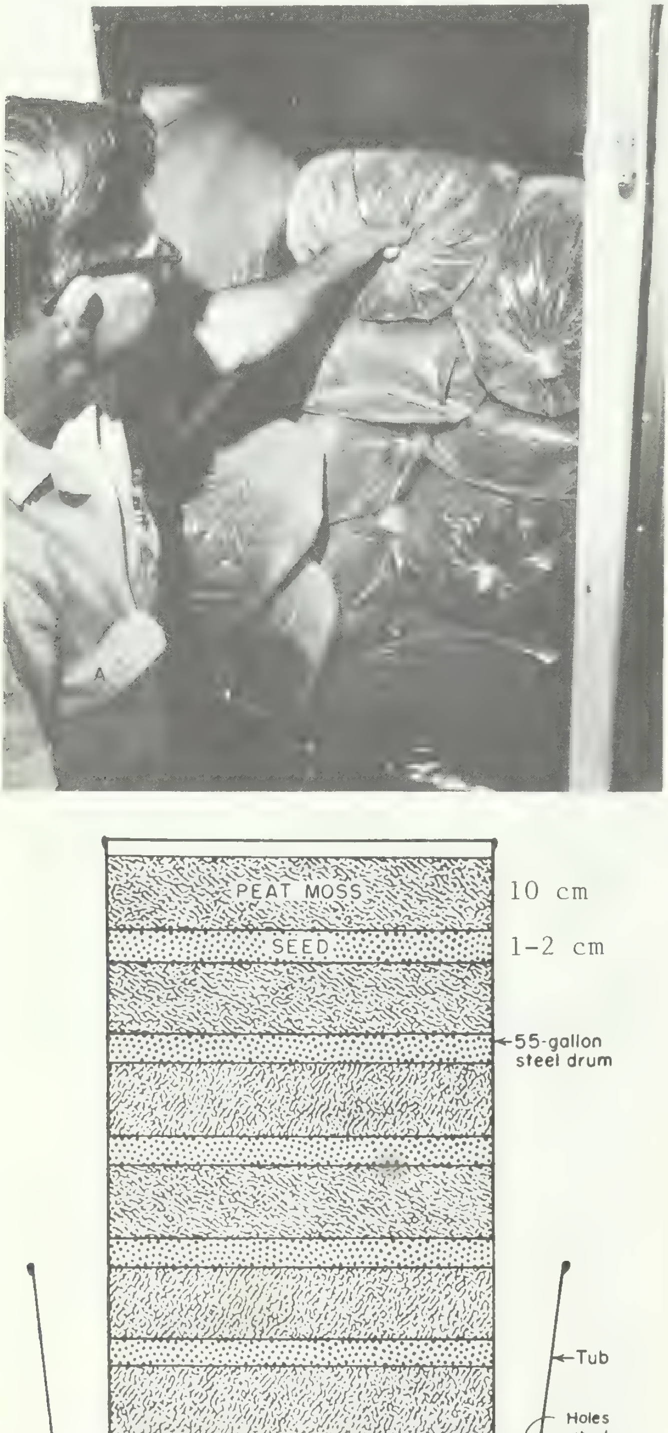

Figure 8-2.—*Stratification can be done (A) for small seed lots by using sealed plastic bags or (B) for large lots by using sealed drums or similar containers.*

Several techniques are used for stratificatio Before subjecting any large seed lots to stratific prior history of their need should be docume Usually, small lots are split and germinated stratified and unstratified seeds through paired

First, decide whether lot size is small enoug pretreating in small plastic bags or large enoug bags and drums (fig. 8-2). Seeds are brought to moisture content by water-soaking them overnig room temperature or up to 4 days for nut-like and pine seeds that have hard seedcoats. Using lots and different soaking periods establishes th soaking time when no information is available.

Second, choose a moisture-holding medium su granulated peat moss, sphagnum moss, or sand. moss is often used because it is slightly acidic like sand, dispels heat well. The medium shou just moist enough that squeezing with one's fi expels some excess water.

Third, seeds are mixed with the treating me The entire mixture is placed in canvas bags in drums or boxes with drainage holes at the botto 8-2). If available, cracked ice is also mixed wit medium to assure rapid and uniform chilling. seed lots are stored alone in plastic bags or with placed over them. Seeds are always stored lo never packed. They can also be laid out on c cloth over moss in drums or boxes. If seeds and ing medium are mixed in the same containe cleaning and separating problem can occur stratification ends.

Drums and bags must be promptly closed to pr seeds and medium from drying out. Seeds medium are inspected every few days for ade moisture. If stratification is 30 days or longer, should be taken out and inspected for mold and d every 2 weeks. When seeds are checked, they s also be thoroughly turned and mixed. Freezi moss at the top of bags can occur but is no cau alarm; it only indicates that the medium is d rapidly and that additional moisture is needed. aeration is indicated by an alcohol odor, a sig anaerobic respiration is taking place. If this o seeds are checked more frequently by opening al and turning the seeds. Recommended storage te ature is 1°C to 4°C.

At the end of the stratification period, seed removed and washed. If seeds and medium we mixed, washing may not be needed; washing re potentially dangerous and damaging m organisms. Immediate sowing is recommende treme drying before use may induce a secon mancy in some species. Most southern pine see be stored under stratification for at least 1 year without loss of viability.

In temperate areas without cold storage faci outdoor stratifying pits are used. Seeds are oughly mixed with sand and kept moist in pit m deep over winter. Stratification occurs during the inter. Where winters are milder, stratifying in boveground beds exposed to more fluctuating temeratures accomplishes the same thing.

Some species in temperate areas require both warm nd cold stratification prior to germination. Examples re green and white ash (*Fraxinus pennsylvanica* and *. americana*) and black cherry (*Prunus serotina*). ropical examples are not documented.

8.3.2 Chemical Alternatives.—Chemical means ave been investigated to eliminate the need for ither cold or warm stratification. Inorganic ions, oranic acids, and growth regulators such as gibbereins have stimulated germination under laboratory onditions (*7*). Germination of dormant and unstratied *Eucalyptus delegatensis*, *E. fastigata*, and *E. regans* was improved with application of gibberellic cid (*2*).

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CHAPTER 9

9. TRADITIONAL SEEDBED PREPARATION AND SOWING

Traditional methods to produce nursery stock include container (*3*, *5*, *14*, *15*, *16*, *27*, *28*,) and bare-root (*1*, *12*, *17*, *29*) methods. Container methods are most common because outplanted seedlings and cuttings (*25*) with attached soil or other growth medium survive well. Where countries use both methods, container systems were probably used first for organized reforestation work. Because container methods can employ many workers of either sex, they are generally preferred in developing countries where jobs are scarce (*18*).

In this chapter, the general preparation and sowing techniques for container and bare-root seedbeds are described. Throughout this guide, seedbed is used in a very broad sense. It means ground-level and raised beds where seeds are sown 1) in or on top of the soil, 2) in pots or containers where seeds are direct-seeded, and 3) in pots where seedlings are transplanted. Transplants are usually germinated in flats but can also be produced in seedbeds. Appendix 9 gives specific procedures for sowing, transplanting, and early tending care of several plantation species.

9.1 Container Systems

9.1.1 Selection Criteria

9.1.1.1 Advantages and Disadvantages.—Container systems are used when reforestation conditions are too harsh (usually too dry and too exposed) for survival of bare-root stock. Even on non-critical sites, potted seedlings have higher survival, and sometimes better growth, than bare-root stock. Advantages of container systems over bare-root systems are:

- good soil is not necessarily needed at the nursery site;
- time in the nursery is shorter;
- roots are not exposed to air and heat during transport to the field;
- faster growth initiation occurs after planting because transplant shock is less;
- planting season can be extended because seedlings are planted with moisture- and nutrient-holding medium around them; and
- start-up time for a new nursery is minimal.

Disadvantages of container systems are:

- they are generally more expensive and time consuming to produce;
- bulky pots pose storage and transport problems;

- fewer seedlings per trip are transported to the field;
- seedling extraction from pots for repacking and transport can be difficult;
- much greater risk of root binding exists after outplanting;
- there is more potential damage to root systems if seedlings are repacked for transport; and
- a continual source of good potting medium is required.

9.1.1.2 Shape/Volume Considerations.—Pot shape and volume both directly influence seedling growth and development in containerized systems. Long pots allow longer and better developed root systems, which are desirable for dry sites (*26*), and short pots produce smaller root systems, which are adequate for moist sites. Size also affects the amount of growth medium needed to fill pots and their holding time in the nursery. Once the available pot root volume is filled, seedlings must be outplanted quickly or root strangulation and spiraling will occur (*24*). Large pots do not always produce the most vigorous stock (*4*).

The ideal container will support growth of high quality seedlings in the shortest possible time. For pines, this means growing seedlings 25 to 35 cm tall in 6 to 8 months, or, if they are "forced" with fertilizers, 4 to 5 months. Too often, the ideal pot for physiological development is not available locally and costs too much to import. The most common container used is the plastic bag. It comes in many sizes and is easily manufactured locally. If imported, costs are moderate to inexpensive, depending on freight distance. Dark plastic is best because, if overwatering occurs, algal and fungal growth are less prevalent in dark plastic than in clear bags exposed to more light. In Tanzania, clear bags were reported better for *P. oocarpa* growth (*22*). Other pot types are clay, split bamboo, tarpaper pots, tin cans, and milk cartons.

9.1.2 Selecting and Preparing Pot Media.—Suitable potting media are cheap, readily available materials in the community and can be economically obtained from inside or outside the country. Alternatives are soil alone; soil/sand mixtures; organic based mixtures with various proportions of peat, compost, sugarcane waste, rice hulls, sawdust, or ground bark; and synthetic mixtures (*9*, *13*).

Soil alone and soil mixed with sand and organic materials are used most often. Usually, soil alone is undesirable because of its weight. If nothing else is available, sandy to sandy loam soil is best; heavy clays are undesirable because water drainage is poor. Alluvial soils are good if their texture is sandy loam to silt loam, but these soils in dry limestone regions are often undesirable because of high clay content and high pH. Organic based mixtures are good because they are light and possess good texture, water-holding capacity, and nutrient retention.

Precise ratios of sand, soil, and composts vary cording to local materials used. Fertility, acidity, physical composition are all different for sand, and clay soils and mixtures with or without soi 1:3:1 mixture of soil/river sand/decayed manur organic materials is a good starting po (Sec. 15.2.2.2). Growth is usually, but not alw poor with sand-only medium (*7*, *10*, *23*).

All materials should be screened free of cl stones, and other debris (fig. 9-1). Screened mater especially soil, can be sterilized but usually is When available, methyl bromide or other fumiga are used rather than steam sterilization (fig. 9 Proper fumigant use is outlined in Appendix 9.

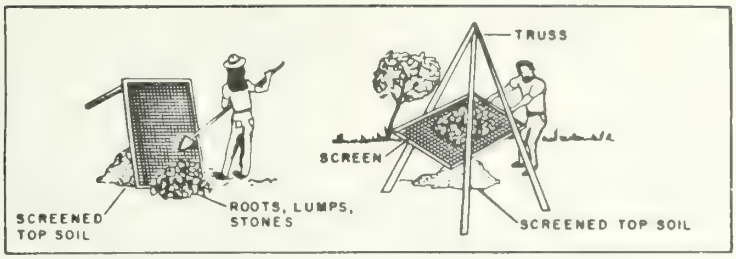
9.1.3 Filling Pots.—Metal or bamboo funnels h direct potting medium into containers. Potting ta for filling are very practical (fig. 9-1), especially w located under a protective shed (fig. 4-3). Light ta ing against the ground or potting table helps se material in plastic bags; *overtamping should neve done*, especially for a medium of high clay cont because compacting reduces drainage and aerat and causes poor root development. Compacted does not have improved moisture retention becaus greater capillary pore space (*8*). Rigid-walled conta ers can be filled with material shoveled from wh barrows, after lining-out the pots in beds. Exc medium dropped between pots promotes weed gro in these interspaces. While some workers are fill pots, others can be setting them out in neat lines rows (fig. 9-3).

9.1.4 Direct-Seeding Method.—Germination centage tests determine the amount of seeds s (Chap. 7). Generally, about 20 percent more seeds sown than the number of seedlings needed to allow natural mortality and culling in the nursery. pendix 9 has a specific example of determining seeds needed for a production run.

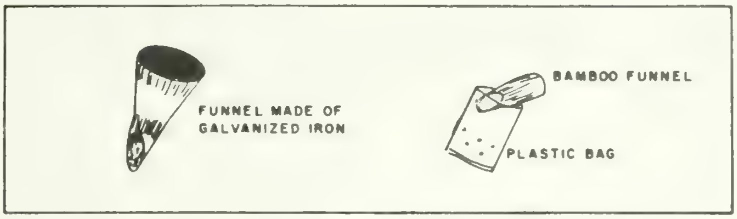
Direct seeding is the placing of seeds on pott medium in pots. Large to medium-size seeds of p and *Gmelina* are best suited for this method; sm seeds are not unless they are pelletized first. Adv tages of direct seeding over transplanting are:

- it avoids additional steps of germinating in tr and transplanting into containers; and
- if two or three seeds are sown per container, number of "filled" containers (i.e., those with least one healthy seedling) is high.

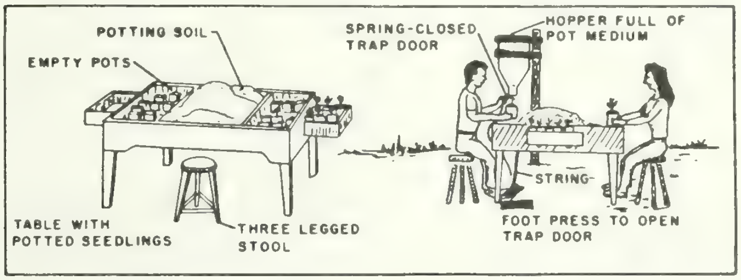
After seeds are sown onto the container medi they are usually covered with a light layer of s vermiculite, or rice hulls that protects them agai animal predation and damage from irrigation wat drops. Direct seeding can be done manually or w machines for round- and irregular-shaped seeds Care must be used in culling excess direct-see plants from pots to avoid damaging the root syste of remaining seedlings (*21*).



SOIL/MIXTURE SCREENING


FUNNEL MADE OF GALVANIZED IRON
BAMBOO FUNNEL
PLASTIC BAG

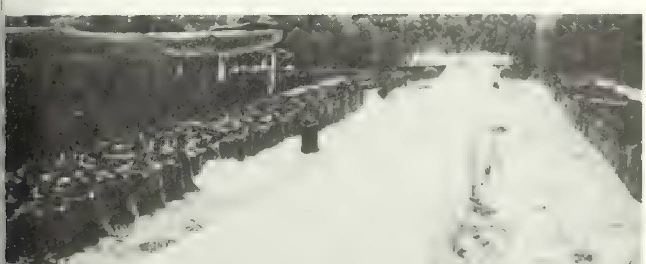
FUNNELS FOR FILLING BAGS, TUBES, OR OTHER CONTAINERS


POTTING SOIL
EMPTY POTS
TABLE WITH POTTED SEEDLINGS
THREE LEGGED STOOL
SPRING-CLOSED TRAP DOOR
HOPPER FULL OF POT MEDIUM
STRING
FOOT PRESS TO OPEN TRAP DOOR

NON - MECHANICAL POTTING TABLE

MECHANICAL POTTING TABLE

Figure 9-1.—*Traditional containerized nursery techniques. Adapted from (32).*



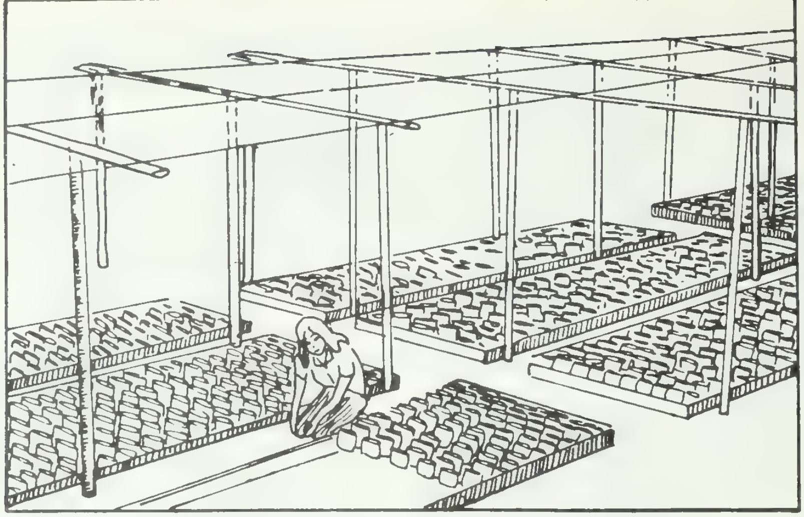
gure 9-2.—*Fumigating soil in large pots with methyl bromide applied under plastic sheeting.*

9.1.5 Transplant Method

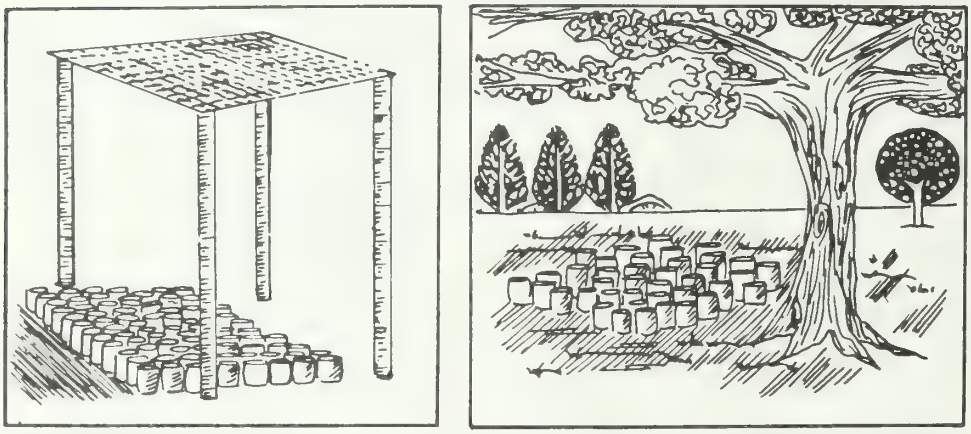
9.1.5.1 Germination Medium.—Possible germination media for seed flats (fig. 9-4) are vermiculite, washed and sterilized river sand or sand/soil mixtures, rice hulls, and tissue paper for very small seeds. Each has advantages and limitations (*19*).

9.1.5.1.a Sand/Soil.—A 1:1 volume mixture of washed sand and soil is the most commonly used germinating medium because both are readily available. Soil and sand may also be used individually. Particle size should be ≥1.7 mm but ≤2.4 mm, as determined by sieve analysis. Particles of this size range do not cohere easily and therefore will not crust over and puddle when water is added. Aeration and drainage properties are also excellent for seedling emergence and growth. Soil and sand used for germinating trays should always be sterilized to prevent disease and weed growth (see Appendix 9).

9.1.5.1.b Rice Hulls.—In many countries, rice hulls are a cheap, local substitute for sand/soil or vermiculite germination media. *Unground* rice hulls are



T-BAR SHADING SCREENS, USING PLASTIC (MAYA) MATERIAL; PALM FRONDS OR BAMBOO KANA SCREENING COULD BE USED



STRAW OR REED MATS OVER POLES

A LARGE SHADE TREE FOR TEMPORARY "FLYING" NURSERIES

Figure 9-3.—*Nursery shading alternatives.*

light, making moving and lifting of germination flats quite easy. Their uneven and irregular packing in flats gives good aeration and drainage, and rice hulls do not decompose during the germination period. Usually, rice hulls are free of most weeds and pathogens; sterilization is used only when contamination is suspected.

9.1.5.1.c Vermiculite.—When available, vermiculite is the ideal germination tray medium because:

- it is sterile and free of pathogens;
- particle size allows aeration and moisture retention;
- reaction of the medium is essentially neutral (pH 7);
- seedlings easily emerge from underneath a covering layer of the medium;
- seedling root growth is unrestricted; and
- seedlings are easily lifted at transplanting because of the medium's physical properties.

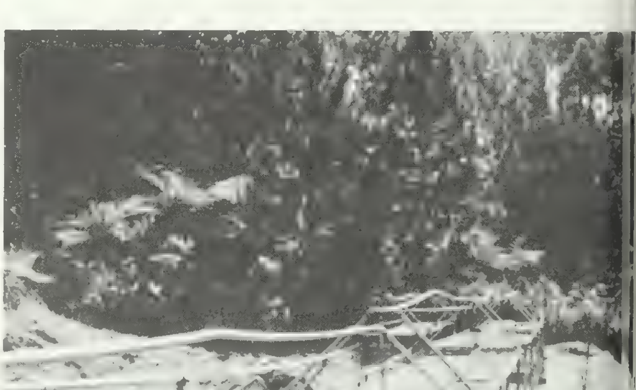


Figure 9-4.—*Standard galvanized metal germination flats.*

The major limitation in using vermiculite is cost, cause it must be imported. Once used, the material n be resterilized and added to potting medium to rease bulking properties (Sec. 15.2.1.2).

9.1.5.1.d Tissue Paper.—Eucalyptus and kadam eds are very small and do not grow or transplant ll if placed directly on any of the above germinating dia. Seeding them first onto moistened tissue paper ch as Kimpak, which is used in laboratory work, proves germination. Paper color or type is irrele- nt as long as it is clean, light, and very porous.

Finally, all of these germinating media are used for nporary physical support of the germinants; they not intended to support physiological growth for g periods. Thus, fertilizers should *never* be applied any of them before germination. Seeds have suffi- nt nutrient reserves in their endosperm to germi- te and grow for a few days until transplanted. If tilizers are applied, damping-off incidence is very gh!

9.1.5.2 Sowing and Germinating.—Germination ys are made from wood or metal. Galvanized metal ys, approximately 30 by 45 by 8 cm, are common g. 9-4). After the trays are filled to within 4 to 6 cm the top, the medium is smoothed and lightly mped.

Seeds are placed on the prepared medium, then cov- d with 6 to 10 mm of vermiculite, rice hulls, or fine sterilized sand; these coverings allow better seedling emergence than soil alone and protect seeds from animals. Sowing deeper than 6 to 10 mm below the surface prevents emergence (*11*). For small seeds (eucalyptus and kadam), special sowing techniques are used (fig. 9-5). Mahogany and other large-winged seeds are de-winged first, then laid flat on the germination medium; pushing seed into the medium causes formation of J-roots (fig. 10-2).

Seeded trays are placed under 20- to 50-percent shade (fig. 9-6) and watered as needed. Shading methods for small nurseries are simple or complex, using metal frames, wooden T-frames, and shade trees for temporary "flying nurseries" (fig. 9-3).

Overwatering must be avoided to prevent damping-off. A simple test to determine if moisture in germination medium is adequate is to squeeze a small portion of medium between thumb and forefinger. If water can be squeezed out, no additional watering is needed.

9.2 Bare-Root Systems

9.2.1 Selection Criteria

9.2.1.1 Advantages and Disadvantages.—Bare-root nursery stock is produced by traditional labor-intensive and mechanized methods (Chap. 16). Species successfully grown by bare-root methods are

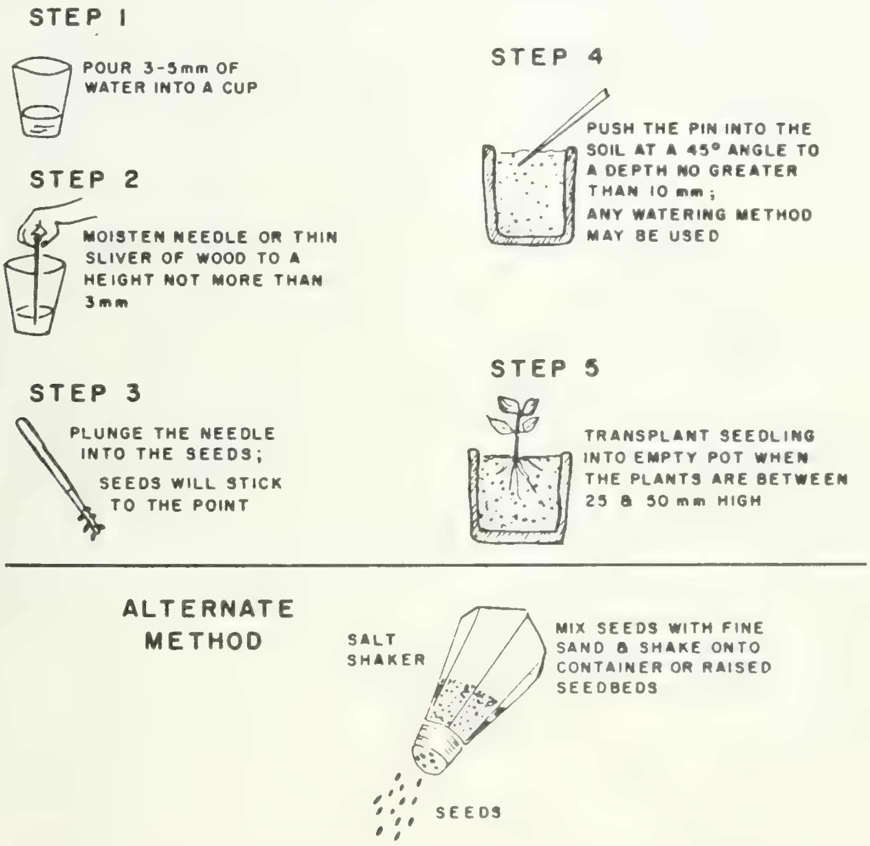

STEP 1
POUR 3-5mm OF WATER INTO A CUP
STEP 2
MOISTEN NEEDLE OR THIN SLIVER OF WOOD TO A HEIGHT NOT MORE THAN 3mm
STEP 3
PLUNGE THE NEEDLE INTO THE SEEDS; SEEDS WILL STICK TO THE POINT
STEP 4
PUSH THE PIN INTO THE SOIL AT A 45° ANGLE TO A DEPTH NO GREATER THAN 10 mm; ANY WATERING METHOD MAY BE USED
STEP 5
TRANSPLANT SEEDLING INTO EMPTY POT WHEN THE PLANTS ARE BETWEEN 25 & 50 mm HIGH
ALTERNATE METHOD
SALT SHAKER
MIX SEEDS WITH FINE SAND & SHAKE ONTO CONTAINER OR RAISED SEEDBEDS
SEEDS

Figure 9-5.—*Seeding very tiny seeds such as eucalypts or kadam. Adapted from (31).*

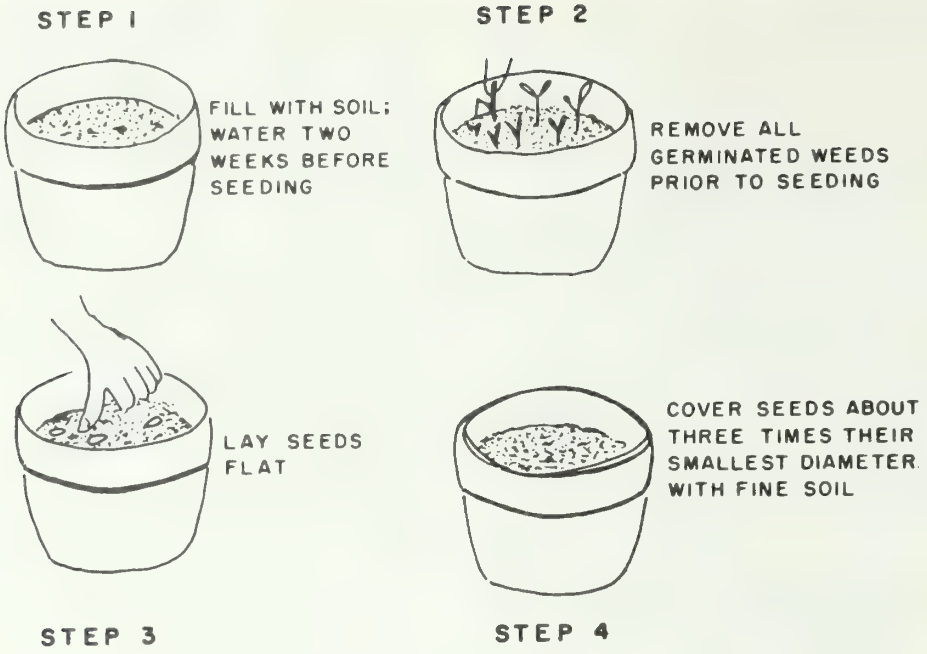

STEP 1
FILL WITH SOIL; WATER TWO WEEKS BEFORE SEEDING
STEP 2
REMOVE ALL GERMINATED WEEDS PRIOR TO SEEDING
LAY SEEDS FLAT
STEP 3
COVER SEEDS ABOUT THREE TIMES THEIR SMALLEST DIAMETER WITH FINE SOIL
STEP 4

Figure 9-6.—*Seeding procedures for medium and large seeds. The same technique can be followed when seeding onto raised seedbeds. Adapted from (31).*

most pines, teak, *Gmelina*, *Casuarina*, and kadam. Advantages of these systems over container systems are:

- sowing seeds directly in ground-level or raised beds avoids transplanting after germination;
- early and later tending care are usually easier;
- there is less weight to transport from nursery to field, allowing more seedlings per trip;
- bundling, handling, and packing are fairly simple for treatment; and
- bare roots are the best type of stock for mechanized planting.

Disadvantages are:

- nursery soils need inherently good physical and chemical properties for permanent use;
- seedlings need 2 to 3 months more time for development;
- damage is potentially greater to roots if they are exposed to air and heat after lifting; and
- large amounts of high-quality irrigation water are required.

9.2.2 Bed Orientation.—Small, shaded bare-root seedbeds in the tropics can run east/west but not north/south as in temperate areas. Because tropical areas are close to the equator, the sun's rays are more direct there than in more northerly or southerly latitudes. An east/west orientation and covered beds (fig. A4-1, Appendix) under sloped roof sheds provide shade during the hottest part of the day for seedbeds. For large bare-root nurseries, available land and its topography will dictate bed orientation.

9.2.3 Fallows.—Fallows or cover crops are gr on idle nursery land to protect against erosion ar build up soil organic matter. Bed areas that have l in fallow should be plowed 4 to 6 months before ing seeds. Allowing grass and weeds to decom first before sowing reduces soil C/N levels to le that do not limit seedling nutrition. A C/N rat 30:1 or less avoids adding supplemental N fertili Typical ratios based on dry weights of C and N alfalfa, 13:1; legume-grass hay, 80:1; oat straw, and sawdust, 250:1.

9.2.4 Cultivation.—Before cultivation, bed a can be fumigated (Sec. 16.2); however, this is ra done in small nurseries. Beds are cultivated by l or implements pulled by horses, oxen, mules, tractors. Hand cultivation is limited to beds 5 shorter (fig. 9-7). Raised beds with protective cove are also used (fig. 9-8). Standard beds are 1.2 m with seven seedling rows. Within beds, soil ca mounded (fig. 9-9) with hand tools or special pl Mounding has several advantages, primarily creased aeration and drainage (*2*) (Sec. 16.1.3). W ways should be at least 45 cm wide between nur beds to allow easy access for weeding and prote control.

9.2.5 Sowing.—Push-type planters or seeders drill seeds and fertilizers to specified depths at same time and cover both in one operation. For s beds, furrows are dug along string and stake gu Seeds are covered to a depth 1 or 2 times their w Fertilizers are placed alongside or underneath s with an intervening layer of soil in-between; if f rs touch seeds or new roots, burning of plant tissue curs, probably resulting in seedling mortality. metimes, seeds are broadcast (direct-seeded) over edbeds by hand or with cyclone broadcast seeders. erage density is 150-300 seedlings/m^2 (*20*, *30*).

9.2.6 ***Mulching.***—After seeding, mulches are read over seedbeds to protect the seeds from animals, erosion hazards, and weeds, and to conserve soil moisture. Many kinds of mulch are used; none must stop germinating seeds from pushing upward to the surface or rot on top of the seedbeds (Sec. 16.3.3). Mulching may or may not influence seedling survival in the nursery through outplanting time (*22*).

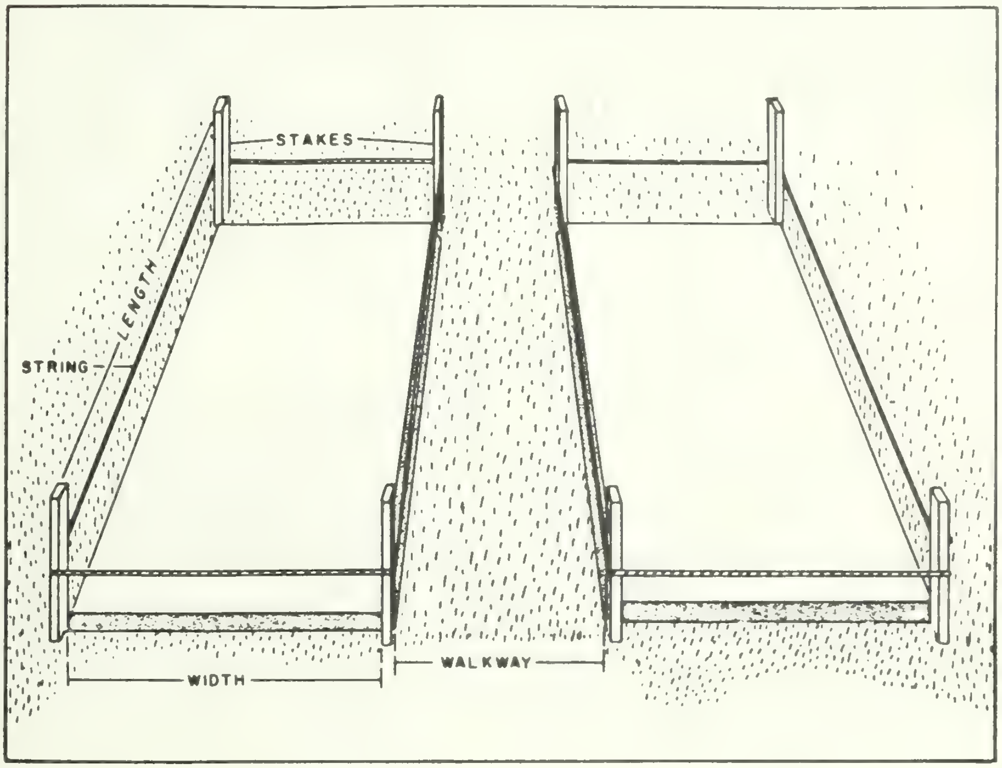
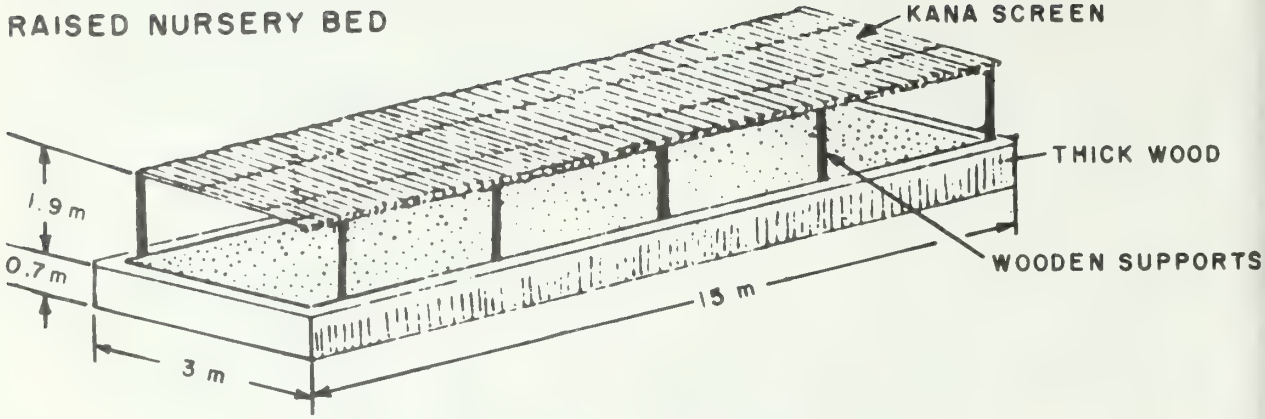
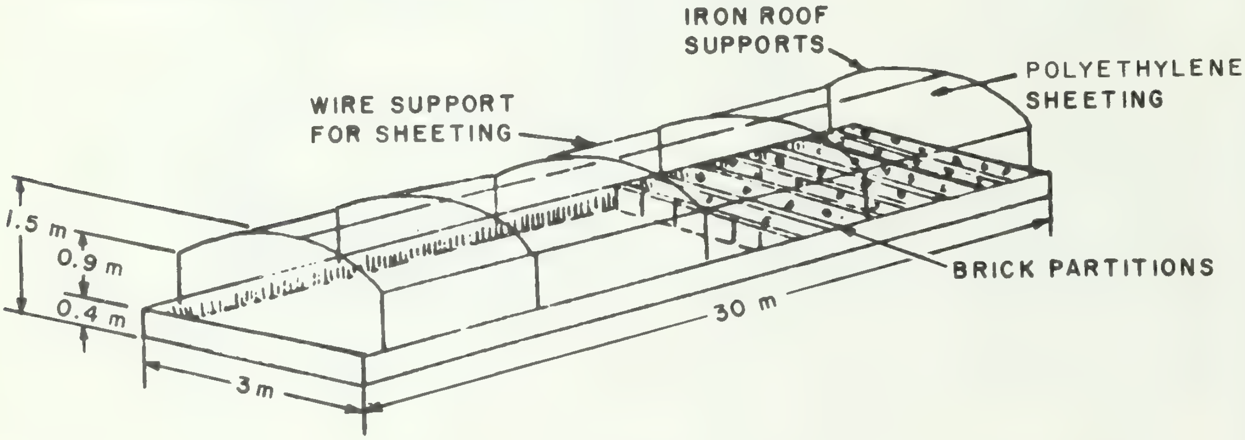


Figure 9-7.—*Proper method of laying-out small, ground-level seedbeds for bare-root nursery stock.*

A. RAISED NURSERY BED



B. SUNKEN BED FOR CONTAINER PLANTS



C. COVERED SHED

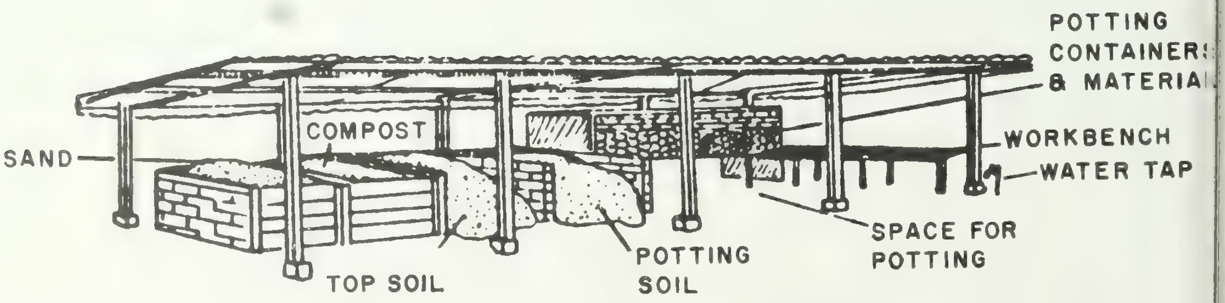
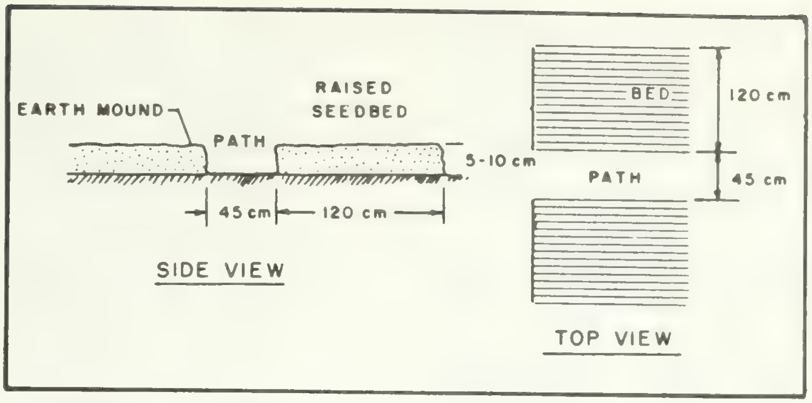
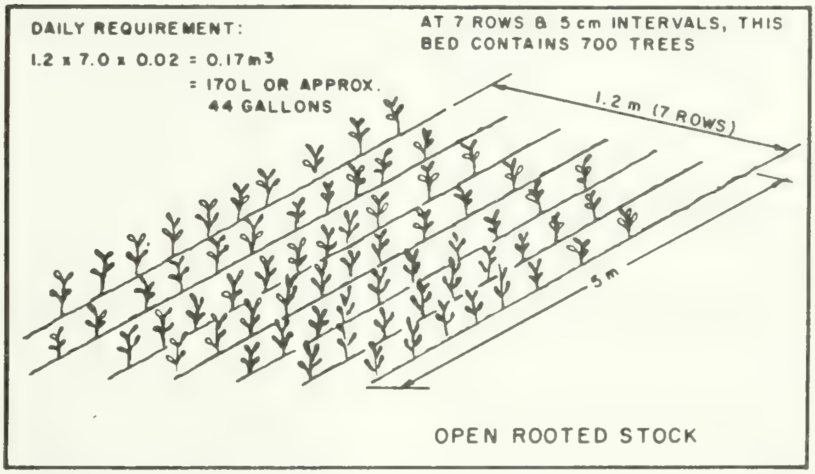


Figure 9-8.—*Nursery structures. Diagrams A and B by A. Krochmal, USDA Forest Service, retired, Asheville, NC; diagram C adapte* *(32).*



A. RAISED SEEDBED FOR OVERHEAD IRRIGATION.


DAILY REQUIREMENT:
1.2 x 7.0 x 0.02 = 0.17m³
= 170L OR APPROX. 44 GALLONS
AT 7 ROWS @ 5cm INTERVALS, THIS BED CONTAINS 700 TREES
1.2 m (7 ROWS)
5m
OPEN ROOTED STOCK

B. WATER NEED CALCULATIONS.

Figure 9-9.—*Nursery bed irrigation considerations. Adapted from (31).*

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CHAPTER 10

10. TRADITIONAL EARLY TENDING OF SEEDBEDS AND CONTAINERS

Container and bare-root systems have similar *early nding* requirements for water, shade, and weeding; rly tending includes the first 4 to 6 weeks of edling growth, including germination. Container stems may be more complex if they include addi-nal steps of transplanting and associated activities. hroughout this discussion it is assumed that ade-ate protection, pest control, and nutritional needs e monitored (Chaps. 12 and 13).

.1 Container Systems

10.1.1 Transplanting

10.1.1.1 Timing.—When transplanting from ger-ination trays, it is essential to avoid stunting of edlings. Transplanting is done after seedlings are large enough to be handled safely but before they get too large and crowded in the trays. The optimum time to transplant pine germinants is 3 to 6 days after emergence and before the seedcoat is thrown (*11*).

For kadam and *Eucalyptus* species, seedlings must be at least 2 cm tall or have four or more leaves that are large enough to handle. Because kadam plants are very small, seedbeds are checked daily to find possible transplants.

Early lifting after germination serves two purposes. First, seedlings are lifted before tap roots develop lateral branches. If lateral roots are stripped off older transplants, lost water absorption capacity causes wilting and maybe death. Second, large root systems are easily bent during transplanting, causing development of J-roots (figs. 10-1 and 10-2).

Transplanting into lined-out pots has two advantages over direct seeding in pots (*3*). First, managers do not have to wait several weeks to see if seedling density is satisfactory; workers *control density* in lined-out pots by transplanting one healthy seedling in each pot. Second, once seedlings are ready for lifting, transplanting can be staggered over several weeks or days. This procedure allows grouping transplants by similar age classes so that outplanting is also spread over a longer period. When bulked seeds of several provenances are used, germination may be uneven because of differences in germination rates (*10*). If this occurs, transplanting delays are the only alternative.

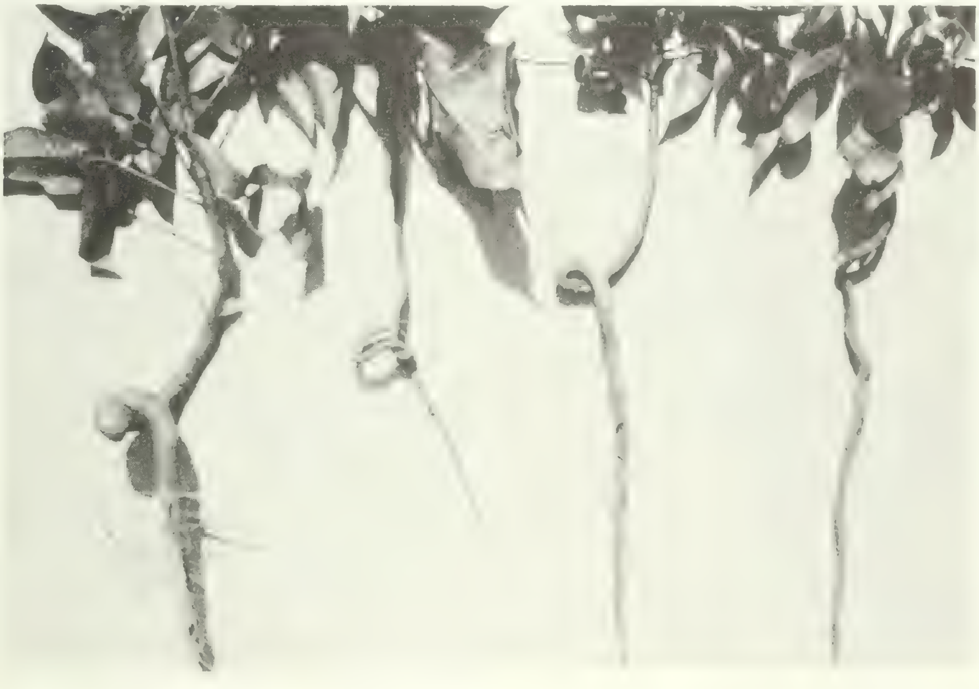
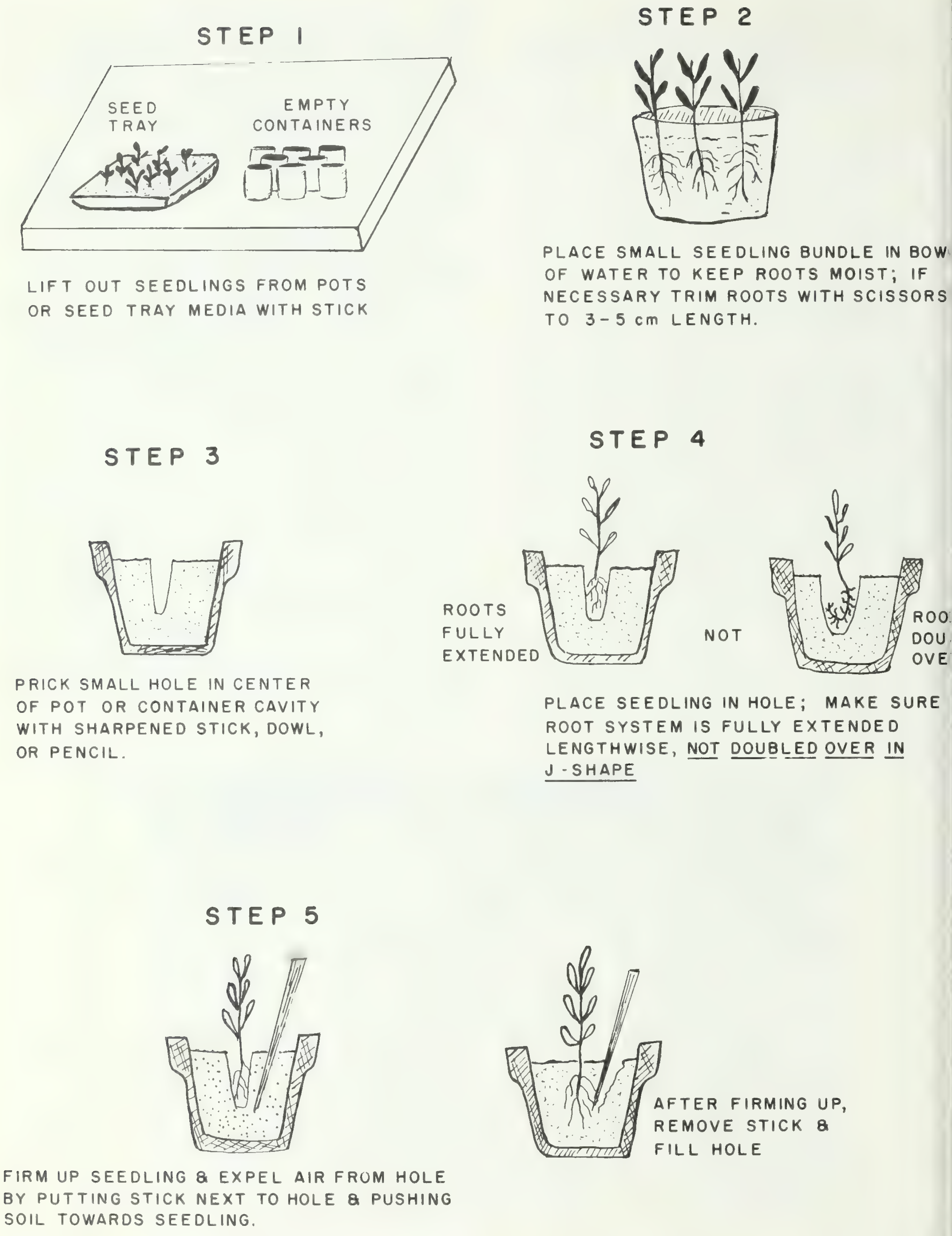


Figure 10-1.—*Typical J-root systems on* Swietenia *(mahogany) caused by improper transplanting from germination trays into pots.*



LIFT OUT SEEDLINGS FROM POTS OR SEED TRAY MEDIA WITH STICK

PLACE SMALL SEEDLING BUNDLE IN BOW OF WATER TO KEEP ROOTS MOIST; IF NECESSARY TRIM ROOTS WITH SCISSORS TO 3-5 cm LENGTH.

PRICK SMALL HOLE IN CENTER OF POT OR CONTAINER CAVITY WITH SHARPENED STICK, DOWL, OR PENCIL.

PLACE SEEDLING IN HOLE; MAKE SURE ROOT SYSTEM IS FULLY EXTENDED LENGTHWISE, NOT DOUBLED OVER IN J-SHAPE

FIRM UP SEEDLING & EXPEL AIR FROM HOLE BY PUTTING STICK NEXT TO HOLE & PUSHING SOIL TOWARDS SEEDLING.

AFTER FIRMING UP, REMOVE STICK & FILL HOLE

Figure 10-2.—*Transplanting or pricking-out procedures.*

10.1.1.2 Procedures.—Seedling roots must be kept noist throughout the transplanting process to avoid lesiccation and death. Workers “prick-out” ppropriate-size seedlings from germination trays nd place them in a small container of water. After oking a small hole in the soil (with pencil, nail, or harpened stick), seedlings are placed in this hole. he soil is then carefully firmed up around each eedling, eliminating air pockets in the root area. irming up seedlings and closing air pockets is done y 1) putting the planting dibble alongside the eedling and 2) pushing soil towards the seedling to ill the cavity (fig. 10-2). One laborer can transplant bout 4,000 seedlings per day; if laborers work in airs, they may plant up to 10,000 per day.

A risk in lifting several hundred seedlings from lifferent germination trays and placing them in a ommon bowl of water to avoid root desiccation is the preading of damping-off and other fungal diseases (*5*,). Submerging infected seedlings in a bowl of water long with other seedlings spreads the disease. There re several solutions. One is instructing trained workrs not to place seedlings with suspected infection in he transplant dish. Another safer solution is filling he transplant dish with a captan solution. Thus, each eedling is treated with captan, minimizing spread of nfection during transplanting. Once damping-off is oticed, the treatments shown in table 10-1 and the recautions given in Appendix 12 are followed.

Another alternative is transplanting seedlings diectly from germination trays into pots, avoiding the use of transplant dishes. This is not usually done for two reasons. First, germination trays are frequently filled with heavy soil or soil mixes, making trays difficult to lift and handle. If a tray is dropped, hundreds to thousands of germinants are lost. Second, wet seedling roots plant better than those coming directly from germination trays.

10.1.2 Resowing.—If germination in direct seeding is unsatisfactory (i.e., many empty containers remain), then containers are resowed. When resowing, containers with seedlings are grouped together in one area, and those without seedlings are grouped in another area of the nursery. Regrouping pots before resowing avoids suppression of young germinants by older germinants from the previous sowing. Excess transplants should be put in separate beds. If voids appear in some beds, they are filled immediately with these extra seedbed transplants. This practice minimizes seedling growth differences among beds and groups seedlings of the same age.

10.1.3 Watering.—Maintaining adequate but not excessive moisture is essential during germination (*2*). Germination trays should be checked two to three times a day; if the medium is moist to fingers but water cannot be extracted by squeezing, moisture is adequate. A fine (mist) spray from overhead pipes or back pumps prevents washing seeds out of the trays (*4*). If overwatering occurs, shade is removed temporarily to speed up evaporation.

Some managers water seedlings immediately after transplanting; added water fills air pockets around the seedlings (fig. 10-2). Small squeeze-water bottles

Table 10-1.—*Treatments to prevent damping-off*

Type of treatment	Point of treatment	
	Seeds	*Germination medium*
A. Steam sterilization (before seeding)	No	Yes
B. Fumigation (before seeding):		
1. Methyl bromide gas	No	Yes
2. Phosphine	Yes	Yes
3. Ethylene dichloride	No	Yes
4. Carbon tetrachloride	Yes	No
5. Carbon disulfide	Yes	No
C. Drenches (after germination/transplanting):		
1. Dexon	No	Yes
2. Captan	No	Yes
3. Ferbam	No	Yes
4. Thiram	No	Yes
5. Zineb	No	Yes
6. Chloroneb	No	Yes
7. Bordeaux	No	Yes
D. Dust (after transplanting):		
1. Mercury	Yes	No
2. Captan	Yes	No

with a long spout are suitable for this operation. Overwatering creates a soupy mixture in a pot and should be avoided to allow adequate aeration of roots (*9*). Fear that heavy rains will damage or wash out young seedlings seems unjustified. In Puerto Rico, significant seedling losses due to rainfall have never been seen, even after severe downpours.

10.1.4 Shade.—Transplanted seedlings should be placed under at least 30-percent shade for 1 to 2 weeks; some areas use up to 85-percent shade (*7*). Although it is possible to transplant *Pinus caribaea* into sun-exposed containers and obtain high survival, this practice is not recommended. Because seedlings suffer the double shock of removal from shaded germination beds and planting in exposed containers, risk of wilting and death is too great.

For raised transplant beds, shade screens are placed high enough above the pots so that workers have access for tending seedlings (fig. A4-1, Appendix). For ground level beds, posts and T-frame structures are screened to similar specifications (fig. 9-3).

Saran (open-mesh plastic sheeting) shade cloth is expensive but quite resistant to damage from ultra
olet sunlight. With proper handling and storage af
use, saran can last 10 years. Other shade materi
are bamboo (kana) screens, palm fronds, and woo
laths.

Small seedbeds can have 20 to 30 percent sha
cover for the first month. In open and sunny are
shade is then gradually removed as seedlings beco
older to avoid undue stress by sudden exposure
sunlight. Some large direct-seeded containerized
erations use no shading unless transplants are used
fill in voids in seedbeds.

Treated wood frames and corner posts last lon
than untreated wood. If hot-cold treated wood is us
is must be dried properly before use so that preser
tive chemicals do not "bleed" onto seedlings bel
them; such chemicals are toxic to plants and man

To avoid edge effects by exposure to sunlight, sar
and other shade materials should extend 0.3 to 0.5
beyond bed borders. Early and late in the day, su
rays are best blocked by dropping screens at ends
the beds. As explained in Chapter 4, greater sha
extension is needed on the south side of nursery be
than on the north side in lower tropical latitudes.

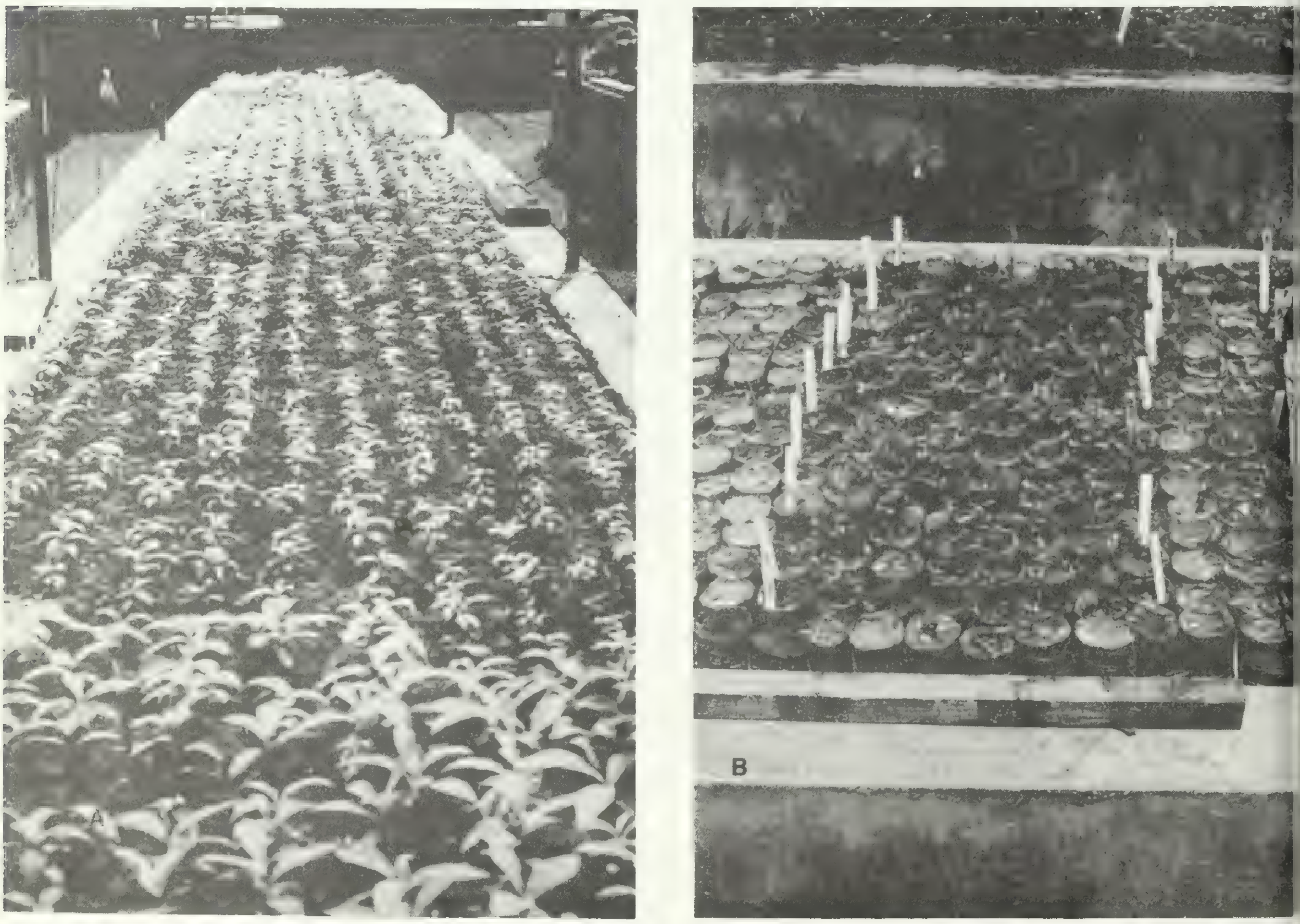


Figure 10-3.—*Early weeding can be done by hand from both sides of small nursery beds for either (A) bare-root* (Cordia) *or (B) containeri* (Araucaria) *stock.*

10.1.5 Weeding.—Only maintenance weeding is eeded in the early weeks after transplanting and rect seeding in pots. Hand weeding is most common. Veeding frequency depends on whether the pot edium was sterilized, the extent of viable weed seed the potting medium used, and the absence or presnce of nearby weed and grass seed sources.

Weeds must be pulled when they are small, young, nd succulent, *before* their root systems develop too uch. When weed roots have spread too far within ots, removing them disturbs seedling roots ig. 16-2). If workers are not careful, entire seedlings re easily pulled out with weeds. When this occurs, it almost impossible to replant 4- to 6-week-old edlings without causing deformed roots.

.2 Bare-Root Systems

10.2.1 Watering.—Bare-root seedlings are more enerally exposed to air and light than container ock. Thus, water needs of unscreened bare-root ock are greater than those of screened container ock (*1*). Beds are checked frequently for moisture nd signs of seedlings wilting. Approximately 100 ters of water are needed daily for a bare-root bed 1.2 y 5 m in size (fig. 9-9). Actual water needs vary by te and are related to bed soil texture, amount of lar radiation received, presence or absence of winds, ecies transpiration rate, and growth stage of edlings (Sec. 16.4.2).

For medium and large bare-root nurseries, fixed rigation systems give best water coverage (*8*). For nall nurseries, water hoses and sprinkling cans may iffice. With any system, water should be applied as roplets; continuous streams of water wash out young edlings. On high clay soils, overwatering causes oot rot due to soil moisture retention.

10.2.2 Shade.—Saran or lath shade can be proided for small ground-level and raised bare-root eds. This technique is impractical for large mechaized operations (Chap. 16). Shading guidelines for raditional bare-root and container nurseries are esentially similar (Sec. 10.1.4).

10.2.3 Weeding.—Guides for weeding traditional are-root and container beds are also similar (Sec. 0.1.5). Hand weeding is practical when beds are mall and labor is plentiful and cheap (fig. 10-3). Vhen seasonal production in bare-root nurseries eaches 100 to 200 thousand plants, chemical control ay be more practical and economical. The major conern is selecting herbicides for weeds that are nonxic to seedlings. Suitable herbicides and precauons to be followed are given in Appendix 12.

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CHAPTER 11

11. TRADITIONAL LATER TENDING OF SEEDBEDS AND CONTAINERS

"Later tending" includes the time from 4 to 6 weeks after germination until lifting and outplanting. This period is distinct from that of early tending; seedlings have passed the "hurdles" of germination and transplanting and are well on their way to becoming healthy, plantable stock. Some hurdles involving weeds, moisture, and lifting still remain. These factors are now addressed, as well as more special steps that promote proper seedling shoot and root growth. As in Chapter 10, it is assumed that protection, pest control, and nutritional monitoring continue simultaneously (Chaps. 12 and 13).

11.1 Container Systems

11.1.1 Grouping, Sizing, and Lining-Out.—Nurseries must produce healthy seedlings having minimal differences in height, root collar diameter, and fo characteristics. In container systems, sortin grouping seedlings in beds by height produces p ing stock of uniform height. In bare-root syst such sorting is impossible and uniform siz achieved by other means (e.g., undercutting, pruning, clipping), which are discussed in Sec 11.2.4, 16.4.6, and 16.4.7.

Where labor costs are low, seedlings are regro as many as three times during their 6- to 8-m stay in the nursery. Because the practice creates ployment, it is defended in areas with high unem ment and low labor costs; the reverse is true for a with high labor costs. Periodic regrouping culls rior stock; this practice reduces lifting and pac chores later and probably reduces disease risk. S lar regrouping is impossible for individual plan multi-cavity block containers but is possible for si cell design systems (Sec. 15.1.6).

Potted seedlings can be lined-out on the grour on other surfaces (figs. 9-3 and 11-1) and in pe nent raised or sunken beds (fig. 9-8). Raising pot blocks and wire screens fosters air pruning of r Placing containers on hard flooring or on pl

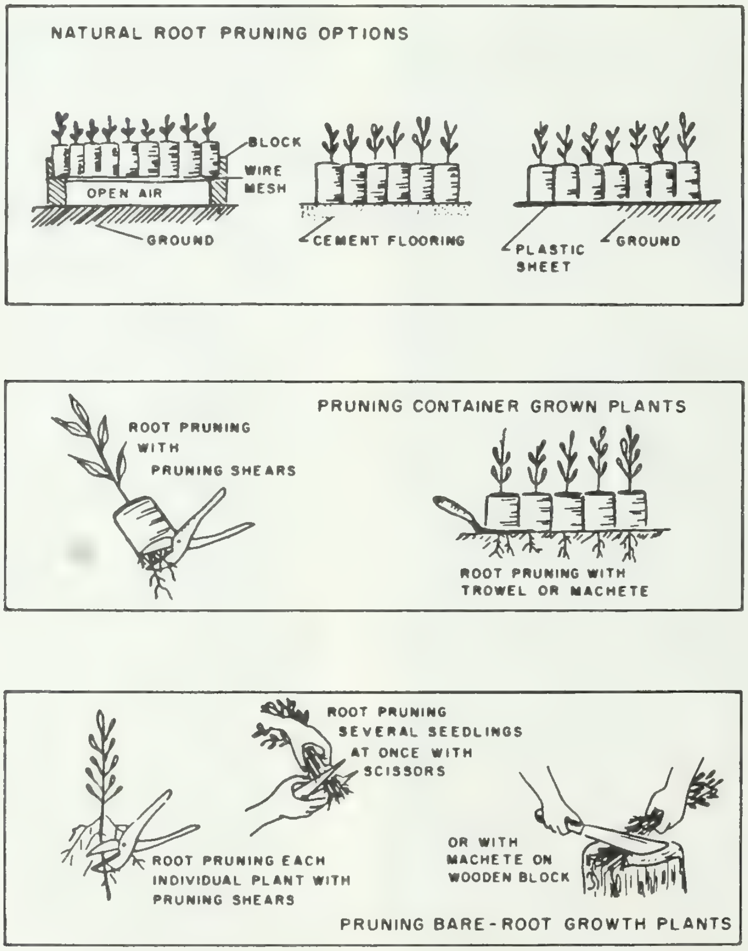
NATURAL ROOT PRUNING OPTIONS
BLOCK
WIRE MESH
OPEN AIR
GROUND
CEMENT FLOORING
PLASTIC SHEET
GROUND
PRUNING CONTAINER GROWN PLANTS
ROOT PRUNING WITH PRUNING SHEARS
ROOT PRUNING WITH TROWEL OR MACHETE
ROOT PRUNING SEVERAL SEEDLINGS AT ONCE WITH SCISSORS
ROOT PRUNING EACH INDIVIDUAL PLANT WITH PRUNING SHEARS
OR WITH MACHETE ON WOODEN BLOCK
PRUNING BARE-ROOT GROWTH PLANTS

Figure 11-1.—*Lining-out, pruning, and lifting of container seedlings. Adapted from (20).*

heeting prevents root egress into soil under pots. If oots egress into underlying soil, lifting and packing re difficult and root damage from stripping is likely.

11.1.2 Inoculation with Mycorrhizal Fungi.—The unction of mycorrhizal fungi on conifer roots is still nder study. They appear to help in mineral (*11*) and ossibly water uptake, perhaps by increasing root surace area. The fact that pines do not grow without ycorrhizal fungi has been documented in Puerto ico (*3*, *18*) and Venezuela (*7*). Thus, all conifer eedlings should be inoculated in the nursery. Mycorhizal fungi can be added to pot medium before translanting or 3 to 4 weeks after transplanting. This chedule avoids treating seedlings still in transplant hock but assures effective inoculation before older eedlings have greater moisture and nutrient requireents.

Mycorrhizal fungi can be sometimes obtained loally or, if not, must be imported. They are collected in uff and mineral soil (0 to 2 cm) from a healthy planation or forest. All material is ground and incorpoated into the pot medium. An alternate method is to each fungal spores from duff material with ambient-emperature water. Water and spores are applied to ontainers from sprinkling cans or back-pump prayers. Water temperatures that are too warm >30°C) can retard fungal growth and seedling develpment (*12*). After 2 to 4 weeks, mycorrhizal fungi hould be visible to the naked eye or with a hand lens.

11.1.3 Watering.—Seedlings should be watered as eeded. This is determined by inspecting potting edium for moisture and by checking for wilting of eedlings. Only combined knowledge and practical exerience with plant stress, different pot volumes and edium used, time since last rainfall or irrigation, urrent moisture status of potting medium, and rowth seedling stage will determine actual watering chedules. Early morning watering is best. By afteroon, excess moisture on seedling foliage has evapoated, thereby reducing chance of disease, which can uild up on moist foliage during warm, humid tropical ights.

As seedlings grow and root systems expand in the ot medium, moisture status is dependent on conainer volume, type and texture of growing medium, nd ability of pots to void excess water through drain orts. Packed clay soil will not allow water to drain ormally throughout the pot. Thus, the medium may e too dry or too wet, depending on how much water s applied. In general, for many pot mixes, if too little ater is applied, most of it runs off without infiltratng. Overwatering saturates the medium and aeraion is reduced.

Indications of poor drainage and aeration are tunted, yellowish-colored seedling foliage and more oncentrated root growth between soil and bag interaces than in the pot medium. In extreme cases, seedlings die because root rot has destroyed the roots (fig. 11-2). If foliage is only yellow, reducing watering frequency and respacing pots to expose them to more sun and drying may help. When foliage turns brown, seedlings are not salvable. New seedlings need a better drained medium and less frequent watering.

Salinity and acidity should be monitored regularly, particularly if nutrients are added with irrigation water (Sec. 15.4.6.1). During hardening-off, watering frequency is gradually, then rigorously reduced (Sec. 11.3.2).

11.1.4 Weeding.—As seedlings grow, increasing foliage area shades the pot surfaces and helps suppress weed growth. Once weeds are established, they must be removed cautiously (Sec. 10.1.5). Usually, hand weeding suffices. Problem areas are edge rows, particularly for ground-level beds. Unchecked weed growth in these areas shades out adjacent seedlings or provides seed sources for nearby containers. Machetes, shovels, hoes, and other small hand tools are used to remove grass and weeds from bed borders.

11.1.5 Shoot and Root Growth Control.—For container systems, shoot growth control is achieved mainly by grouping seedlings of similar height in the same beds (Sec. 11.1.1). This practice keeps fast-growing seedlings from overtopping and shading out slow-growing ones. If limited overtopping of seedlings occurs and neither additional regrouping nor outplanting are imminent, the fastest growing individuals can be clipped back. This slows top growth and enhances root growth. There must be sufficient pot volume to accommodate extra root growth or root spiraling will result.

Root growth of potted seedlings is controlled by effective pot volume and depth. Once roots fill this volume and reach the pot bottom, seedlings must be out-

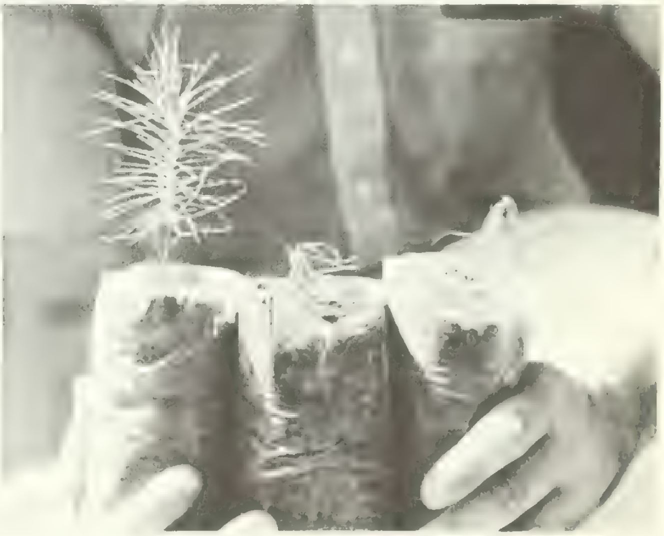

Figure 11-2.—*Effect of overwatering and poor drainage on potted nursery seedlings.*

planted. Extra holding time causes root spiraling or strangling. Knowing seedling shoot and root growth rates and outplanting dates are crucial for selecting optimum pot volume and for controlling root and shoot growth.

If unforeseen difficulties delay outplanting beyond 1 to 2 months, two alternatives exist for "holding over" seedlings. If labor is cheap and abundant, seedlings are repotted into larger containers that will accommodate larger root systems. When repotting is not feasible, severe root pruning is needed before outplanting. In both instances, survival and growth performance of hold-over seedlings in the field will probably be less than that of seedlings planted on time.

11.1.6 Lifting and Transporting.—Root systems of containerized stock are self-contained and protected by pot walls. Fewer precautions are needed in lifting and transporting containerized stock than are needed for bare-root stock. If roots have grown through pot bottoms, they must be pruned and trimmed before loading (fig. 11-1).

Containers are placed in transport flats, loaded
trucks, and securely tied (fig. 11-3). Because w
burn is a real threat to seedlings, truck beds are
tirely enclosed with a tarp to protect them from w
and sun. Drivers should inspect tarp fastenings o
sionally, making sure they are secure and that w
is not blowing on seedlings.

A 5- to 8-cm head space between each laye
seedlings is left on the truck beds. If light-wei
growth medium is used, several tiers can be loade
trucks without creating a topheavy load. But if
potting medium is soil, fewer tiers are possible
cause greater weight can create a topheavy condit
endangering truck and driver when maneuver
curves.

In temperate climates, anti-transpirants are so
times sprayed on seedling foliage before transport
them. Use of anti-transpirants is not usually ne
sary for seedlings in the tropics because they are
stored as dormant stock. Yet, if seedling tops are
large in relation to container root volumes and th

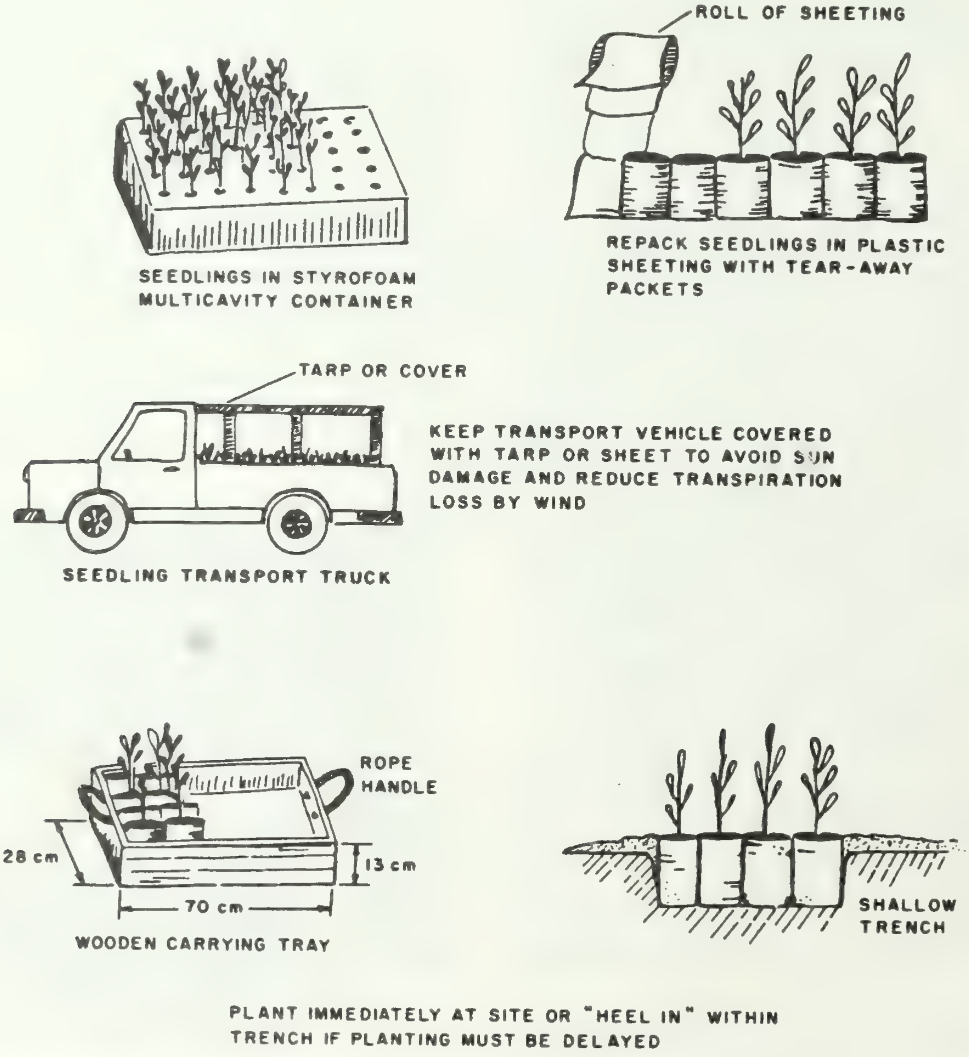
ROLL OF SHEETING
SEEDLINGS IN STYROFOAM MULTICAVITY CONTAINER
REPACK SEEDLINGS IN PLASTIC SHEETING WITH TEAR-AWAY PACKETS
TARP OR COVER
KEEP TRANSPORT VEHICLE COVERED WITH TARP OR SHEET TO AVOID SUN DAMAGE AND REDUCE TRANSPIRATION LOSS BY WIND
SEEDLING TRANSPORT TRUCK
ROPE HANDLE
28 cm
13 cm
70 cm
WOODEN CARRYING TRAY
SHALLOW TRENCH
PLANT IMMEDIATELY AT SITE OR "HEEL IN" WITHIN TRENCH IF PLANTING MUST BE DELAYED

Figure 11-3.—*Transporting of nursery seedlings to field outplanting sites.*

s danger of excessive transpiration, anti-transpirants ould possibly be used to reduce short-term water loss. mall research trials will determine the effectiveness f such treatment.

1.2 Bare-Root Systems

11.2.1 ***Inoculation.***—Seedlings in bare-root beds re inoculated with mycorrhizal fungi, using forest uff and mineral soil or water-borne spores, following rocedures used for container beds (Sec. 11.1.2). Inoclation is done before sowing or before seedlings are 4) 6 weeks old. If healthy plantations exist around are-root beds (fig. 11-4), natural inoculation may be dequate, especially when bed soil is not sterilized.

11.2.2 ***Watering.***—Generally, bare-root beds have reater water needs than container beds because of heir greater environmental exposure (Sec. 10.2.1). lder bare-root seedlings have greater water needs han younger seedlings. Thus, almost daily watering s required until hardening-off is started. Soil moisure must be checked often in well-drained, porous eds. Bed soils with more clay lose moisture less apidly.

Damaging effects of irrigation droplet impact are inimal for older, larger seedlings. Exceptions are aky pipes where escaping water can destroy large reas of beds and seedlings (fig. 16-4).

11.2.3 ***Weeding.***—Openness of bare-root beds faors more weed growth than do container beds. Hand weeding suffices for small nurseries; mulches are usually too troublesome to be effective (*15*). For large bare-root nurseries, only herbicides give dependable, long-term control, up to 30 days and longer between applications. When herbicides are unavailable, dilute concentrations of kerosene or other mineral spirits also control weeds fairly well in pine bare-root beds (Sec. 16.4.1). Before applying any herbicide, one must ascertain that its effectiveness is specific only for the plants treated and not toxic to seedlings (*8*, *16*).

11.2.4 ***Shoot and Root Growth Control.***—Undercutting, lateral pruning, and top pruning are techniques to control root and shoot growth of bare-root nursery stock. Root wrenching is practical only in large, mechanized bare-root nurseries. In very small nurseries, none of these techniques may be used because the scale of operation does not demand quality-control stock. Sections 16.4.6 and 16.4.7 contain more detailed discussions of all shoot and root control operations that are used in bare-root nurseries.

Undercutting is done with machetes and shovels in small nurseries (*14*, *17*) and with tractor drawn machines in large nurseries. Clean severing of taproots stimulates lateral root growth but stops shoot growth. The technique is effective in manipulating shoot/root ratios.

Lateral root pruning severs roots between adjacent seedling rows. The technique allows easier lifting of seedlings before packing and transporting. Machetes or machines are used, depending on nursery size.

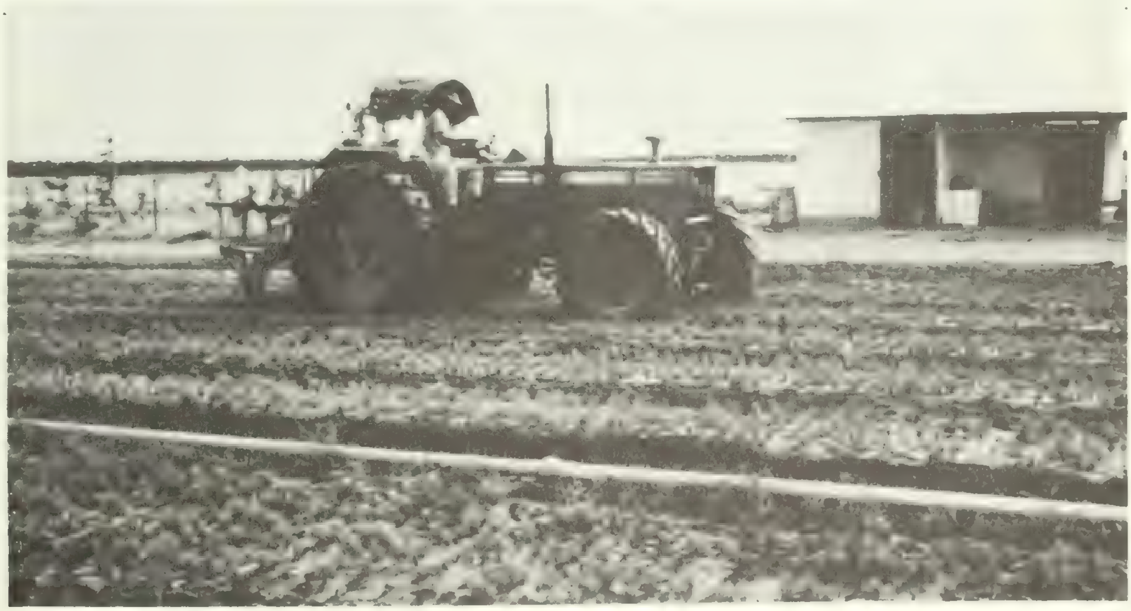

Figure 11-4.—*Pine plantations around a nursery complex serve as inoculum sources of mycorrhizal fungi, naturally by wind-borne spores and artificially by man; the latter procedure must be used when bare-root beds are fumigated. Note that area directly behind work shed was cleared and prepared for new beds so that old beds could be fallowed. Leaving three to four rows of trees would have retained windbreak effect of that area for existing beds.*

Top-pruning (clipping) controls excessive shoot growth. The technique is used selectively for individual seedlings that are overtopping others and for entire beds when all seedlings have grown too fast and must be kept longer before lifting. The operation stimulates root growth and is another method of manipulating shoot/root ratios. Hand shears are used in small nurseries and tractor drawn mowers in large nurseries.

11.2.5 Lifting and Transporting.—The four procedures for taking bare-root seedlings to the field are lifting, protecting, grading, and transporting. Stock should be lifted with shovels, never pulled directly from the soil; the latter can strip rootlets from seedlings, particularly if they are pulled from dry, clay soil. Soil is shaken off roots, which are immediately washed, trimmed, and then stored in water, water slurries, or wet peat moss.

Grading separates plantable from cull seedlings. Grading standards vary by species and geographical area but usually include height, stem caliper, shoot/root ratios, foliage condition, and root mass. For some species, such as neem (*Azadirachta indica*), khaya (*Khaya* sp.), and mahoe, side leaves may be stripped to minimize water loss from tissues (*19*) (fig. 11-5). Only larger, well-developed seedlings should be planted; evidence shows that large seedlings outperform small ones, even up to 5 years after outplanting (*2*). If plants are too large, pruning them back to a total length of 18 to 30 cm may improve outplant survival (*13*).

Planting within a few hours of lifting, or at least same day as lifting, is the key to successful outpla ing of bare-root stock (*4*, *5*). If transporting and pla ing delays cannot be avoided, *do not lift seedlin* Seedling roots must be kept cool, in the shade, a moist at all times after lifting and while being tra ported to planting sites (*1*). Section 16.5 gives otl lifting and transporting hints for large bare-root nu ery operations.

11.2.6 Stump Planting.—Some species such Cassia, Gmelina, and teak withstand trimming of major portions of the seedling stem and root syst (*9*). The result is a stump, some 15 to 30 cm long (11-5). Stumps are easily bundled, packaged, a shipped. Weight is minimal, and many more seedli are moved per day as compared to containerized a bare-root operations. Shade and protection instr tions for stumps are the same as those for bare-r and containerized stock.

11.3 Other Later Tending Considerations

Several nursery operations already mentioned ha particular influence on lifting and outplanting s cess. They are discussed separately to emphasize th importance.

11.3.1 Shoot/Root Ratios.—Determining sho root ratios is one way to assess overall seedling hea and suitability for outplanting. This is done by me uring oven dry weight or volume of seedling tops a

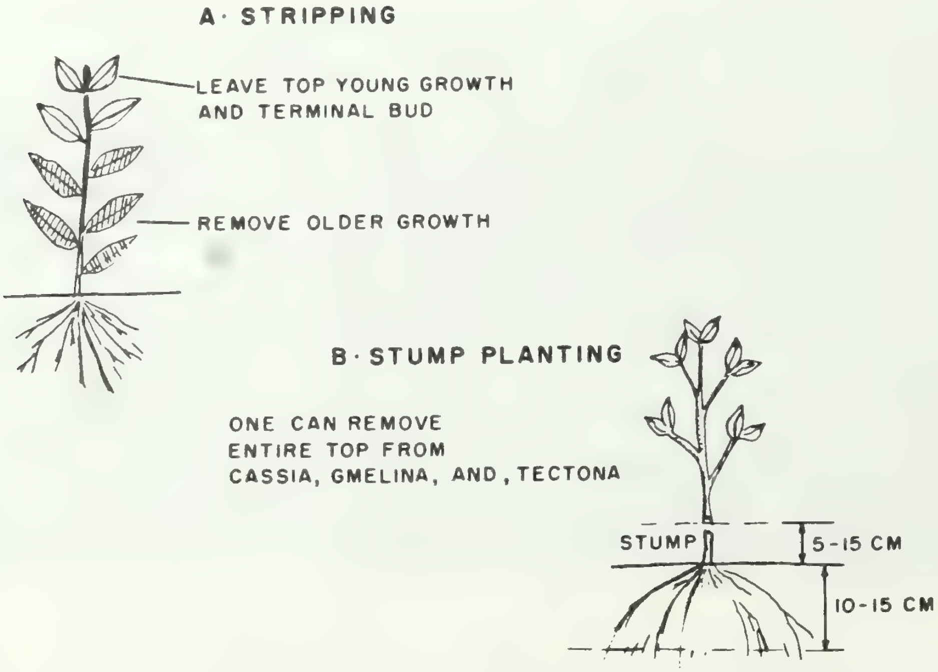
A · STRIPPING
LEAVE TOP YOUNG GROWTH AND TERMINAL BUD
REMOVE OLDER GROWTH
B · STUMP PLANTING
ONE CAN REMOVE ENTIRE TOP FROM CASSIA, GMELINA, AND, TECTONA
STUMP
5-15 CM
10-15 CM

Figure 11-5.—*Procedures for (A) stripping seedlings before transplanting to field or (B) making stumps for outplanting. Taken from (19).*

viding by oven dry weight or volume of seedling
ots. Shoot-to-root dry weight ratios of 2:1 are accept-
le for most seedlings. Higher ratios usually indicate
cessive shoot growth for corresponding root growth.
The ratio limit (2:1) must be used cautiously, how-
er, because ratios can be affected by shading and
ntainer type (tables 11-1 and 11-2). Actual pot vol-
nes and shapes will limit root weights to certain
aximum values unless undesirable spiraling occurs
thin pots.

Type of pot medium also affects root branching and
velopment. Root branching is greater in medium
th peat, perlite, and vermiculite than in soil-only
edium due to the superior aeration properties of
il-less medium. In soil-only medium, greater devel-
ment of tap roots and less lateral branching tend to cause root curling or spiraling at the pot bottoms, especially when holding time in the nursery is too long. Large spreading root systems are best because of 1) their greater capacity for absorbing water and nutrients from soil or pot medium and 2) greater surface area from which to extend new lateral roots after outplanting. Planting density also affects the root collar diameter growth of seedlings (*6*).

11.3.2 Hardening-Off.—Special seedling care and treatment in the nursery allows production of green, healthy, and vigorous seedlings of sizes suitable for outplanting. To grow large seedlings in short periods, water, fertilizer, and shade are used to stimulate rapid growth. However, "forced growth" regimes usually produce succulent seedlings that do not survive harsh conditions at planting sites. The hardening-off

Table 11-1.—*The effect of different shade levels on the height growth, survival, root collar diameter, and shoot/root dry weight ratios of seedlings of* P. caribaea var. hondurensis[1]

Measurement	Percent shade level			
	0	20	35	77
Height (cm)	14.1	16.8	21.3	25.0
Survival (%)	95.3	98.5	98.0	97.5
Root collar diameter (mm)	2.31	2.34	2.26	1.90
Shoot/root dry weight ratio	2.17	1.86	2.23	9.83
Mean dry weights (g):				
With LSD:				
Shoot	0.713 ± 0.190	0.706 ± 0.148	0.726 ± 0.182	0.509 ± 0.132
Root	0.367 ± 0.132	0.446 ± 0.164	0.379 ± 0.142	0.070 ± 0.044

[1] Each shade level represents the mean of 600 seedlings. The seedlings, 6 months old at the time of measurement, were grown in Styroblock 8 cavities filled with a peat-vermiculite mixture at the ITF experimental nursery in Puerto Rico.

Table 11-2.—*Influence of container type on root collar diameter, height, and shoot/root dry weight ratios of seedlings of* P. caribaea var. hondurensis[1]

Container type	Volume of containers	Root collar diameter	Shoot/root dry weight ratio	Height
	Cc	*Mm*		*Cm*
Polyethylene bags	500	5.36	2.42	36.8
Rootrainer	175	2.88	2.95	22.4
Polypot	250	2.86	2.19	22.4
Polypot	175	2.30	2.47	21.6
Polypot	100	2.11	1.65	18.1
Kraft paper tube	305	3.13	5.04	25.2
Kraft paper tube	190	2.85	6.09	19.9
Styroblock 8	120	2.11	2.59	25.1
Styroblock 4	60	1.78	1.63	21.8

[1] The containers were filled with a peat-vermiculite mixture; no fertilizer was added. The seedlings were direct-seeded, 4 seeds per cavity, and culled to 1 seedling after 2 weeks. The data were taken 6 months after sowing at the ITF experimental nursery in Puerto Rico.

process increases probability that seedlings will survive transplant shock. The process conditions both containerized and bare-root grown seedlings to survive without water and shade as long as possible in the nursery before they are outplanted.

If seedlings have been under continuous shade, the shade should be removed, conditioning seedlings to full sunlight. In the beginning, shade should be removed gradually for 2 hours during the day or for 1 hour in the morning and 1 hour in the afternoon. After 3 or 4 days, length of the shade period is reduced another 1 to 2 hours. By extending shade-free time gradually, seedlings will tolerate full sunlight with a minimum of shock within 2 to 3 weeks. Keeping 40- to 50-percent shade throughout hardening-off, as is done in some countries (*10*), is not recommended.

Hardening-off also involves reducing the amount of water available to seedlings. One method is to gradually extend the time between watering periods by 2 or 3 days. The number of waterless days is progressively extended until seedlings are capable of surviving up to 2 weeks or longer without water. In hardening-off, wilting must be avoided. If it does occur, water is applied until wilting stops; then water reduction begins again, but at less severe regimes.

When hardening-off seedlings in container beds, certain relationships between pot volume, potting medium, seedling size, and hardening-off must be considered. If pot volume is small (less than 150 cc) and filled with a peat: vermiculite medium, hardening-off seedlings for much more than 2 weeks is not possible. Older seedlings will transpire relatively large amounts of water from small containers filled with porous medium. Thus, nursery managers should observe and carefully record all information related to watering, wilting, and density in seedbeds. When information is properly assessed, seedbeds can be efficiently managed with little loss due to improper hardening-off. With accurate information, nursery managers can also tell silviculturists and farmers how often seedlings should be watered if they must be stored for extended periods before outplanting.

11.3.3 Culling J-Root Plants.—Malformed taproots are common among hardwood seedlings grown in nurseries (fig. 10-1). When seedlings are improperly transplanted from germination trays to containers, bent or J-roots occur (fig. 10-2). This is a serious problem because seedlings with J-roots fail to develop properly in the field, and older trees with J-roots are more susceptible to windthrow.

The J-root can be avoided if young seedlings are used and they are carefully placed in transplant holes (Sec. 10.1.1.2). It is best to transplant seedlings *before* lateral root branching occurs and before the seedling flush develops.

To avoid bent roots in transplanting, seedlings are pulled through a transplant dish filled with water. The roots trail and coalesce as seedlings are pulle through and lifted from the water. Seedlings are stuc into the hole as deep as possible, pulled up t straighten their roots, and then firmed up with a dil ble stick (Sec. 10.1.1.2). If roots are >8 cm long, the should be trimmed back to about 5 cm in length.

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CHAPTER 12

12. PROTECTION AND PEST CONTROL

Nursery stock requires a large investment of time, bor, and monetary resources. Without protecting is investment, large seedling losses may occur (*3*,). Such losses can be catastrophic when communi- s need seedlings to produce firewood or protect crit- l watersheds. Large and small nurseries need pro- ction from several physical and environmental ments, as well as from insects and diseases.

12.1 Property and Seedling Security

Daily guard service to protect seedlings and property is very costly. However, it may be the only alternative in areas where animal and human populations are very high, and where small tools can be easily stolen and seedlings destroyed. In poor communities, payment to workers in food rather than direct cash may be best.

Adequate fences deter animals and people. Fences built of treated wood and with proper materials last a long time. In some projects, replacement posts can be harvested from field plantings. When diesel oil and pentachlorephenol are available, hot-cold treating of posts in barrels or drums is relatively inexpensive. Live fences and hedges with thorny plants or local shrubs may be adequate. Diagrams are available on how to construct self-closing gates and other fencing structures (*22*).

Windbreaks reduce dry winds that evaporate moisture from seedbeds (*16*). Local tree species are preferred, but prolific seeders such as *Leucaena* are avoided. Wind blown seed from windbreaks germinate and compete with seedling root systems growing in seedbeds and germinating trays. Removing these invaders is costly, and root systems of seedlings are disturbed in weeding.

Where fires are frequent, a 2- to 3-m firebreak should be maintained around the entire nursery (*22*). Water outlets should be located at several places near the perimeter so that water is readily available if a fire jumps the firebreak.

12.2 Pests and Diseases

Diversity of climate and environments in the tropics precludes simple prescriptions for insect and disease problems of forest nurseries. This chapter is therefore a brief review of some potential problems and is not all-inclusive. A summary of major pests, species attacked, symptoms, and recommended treatments is given in table 12-1.

12.2.1 ***Symptoms.***—When seeds (*5*) or vegetative materials are collected or imported from outside a country, they should be checked immediately upon arrival at the nursery for symptoms of disease or insects. Unfortunately, phytosanitary certificates do not always guarantee that undesirable insects or diseases are absent in imported seeds or plants.

Some insects are apparent from chewed leaves; others are seen on the underside of leaves. Webs and eggs are other signs of infestation. Some common pests are those in figure 12-1.

Disease symptoms can include sooty appearing materials, a form of fungus; rust spots; irregular-shaped blotches or mosaics of different colors; and sticky discharges. Discoloration symptoms can be caused by either disease organisms or by mineral deficiencies (Sec. 13.2).

Table 12-1.—*Summary of major nursery pests and diseases, forest species attacked, and control treatments recommended*

Pest type	Seedling species affected	Control
Insect animal types		
A. Chewing mouth parts:		Ingested poisons:
Cutworms	Mahogany, teak, pines	Spectracide, chlordane
Crickets	Teak	General insecticide
Leaf miners	Mahogany	General insecticide
Shoot borers	Mahogany, Spanish-cedar, and other Meliaceae family species	Systemic insecticides
Sugarcane root/stalk borers	Mahogany	Soil drench insecticides
B. Piercing/sucking mouth parts:		Contact poisons:
Aphids	Teak, kadam, *Gmelina*	Various
Mealybugs	Teak	Various
Thrips	Kadam	Various
Scales/mites	Pines	Various
C. Large pests:		Various controls:
Spiders	Pines	Ingested/contact poisons
Birds	Pines/hardwoods	Chemical repellents added to seeds
Rats/mice	Pines/hardwoods	Chemical repellents; cover seeds; pet cat in nursery
Diseases		
A. Damping-off fungi	Pines/hardwoods	Pot media and soil sterilization; soil drench fungicides
B. Seedling needle blight	Pines	Various fungicides
C. Brown needle disease	Pines	Bordeaux mixture (i.e., copper sulfate)
D. Root rot fungi	Pines/hardwoods	Soil sterilization; good watering control and monitoring

12.2.2 Control.—When insects or diseases occur, control measures are needed quickly. Appropriate chemicals are applied (*10*) and are used according to labeling instructions, with respirator (mask) and adequate clothing to reduce risk of toxicity to humans during application. The kind of control used depends on which pesticides are locally available and the kind of pest. Sometimes, removing affected seedlings is sufficient.

Insects are divided into two major groups: those that chew leaves and those that suck juices out of plants. The controls for each are quite different. For insects with piercing-sucking mouth parts, a direct contact poison is required, i.e., one that covers and kills them. For those insects with chewing mouth parts, toxic substances deposited on leaves are ingested and eventually cause death.

12.3 Common Chewing Pests

12.3.1 Pine Seedling Cutworm.—Cutworms
noticed when they are about 2 mm long, shortly a
emerging from eggs. Larvae feed for 1 or 2 days, ch
ing on tender needles near the seed cap. Follow
emergence, they are light yellow in color with a t
brown stripe down the back. As the larvae feed,
gested chlorophyll is absorbed, and they develo
deep green color.

Cutworm larvae eat cotyledons at their point of
tachment on the stem; the cotyledons are complet
severed, and the seedcoats fall to the ground. O
cotyledons are severed, larvae crawl downward,
the hypocotyl, and then proceed to other seedlin
After they grow to about 25 mm long and turn li
brown, cutworms are easily observed crawling am
seedlings. Before burrowing into germinat

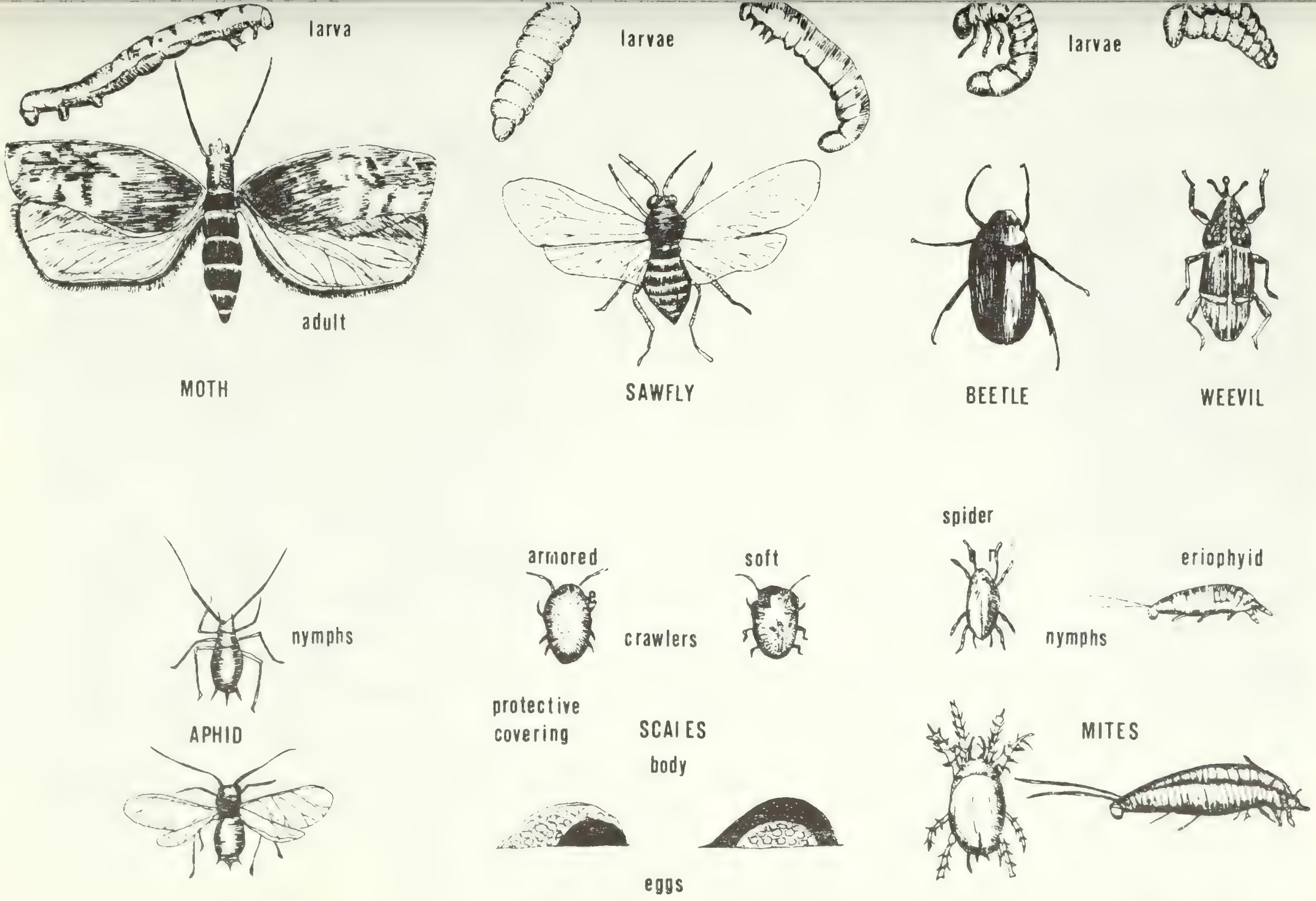

Figure 12-1 —*Common nursery insects. (Drawing from A. Krochmal, USDA Forest Service, retired, Asheville, NC).*

medium for metamorphosis, each cutworm can destroy 20 to 30 seedlings.

Cutworm attack occurs year-round and has been observed on both *P. caribaea* and *P. oocarpa* seedlings (*13*). Cutworms have also killed teak and mahogany seedlings in East Africa. Effective controls were chlordane at 0.45 kg active ingredient (A. I.) per 378 liters of water or Zectran at 0.23 kg per 378 liters of water. An insecticide such as Spectracide can also control cutworms.

*12.3.2 **Crickets and Termites.***—Other common stem chewers in East Africa are crickets and termites. Major activity was limited to teak seedlings. Several insecticides controlled these pests (*13, 15*).

*12.3.3 **Leaf Miners.***—Mahogany seedlings are also attacked by leaf miners that lay eggs on the backside of the leaf. Leaf miner larvae cause seedling leaves to curl. Although leaves die, seedlings ordinarily survive; thus, leaf miner attacks are not a serious problem.

*12.3.4 **Shoot and Root Borers.***—Perhaps the most serious insect attack in tropical nurseries is that of shoot borers on mahogany and Spanish-cedar seedlings. Although seedlings are seldom killed, the economic damage is high. A major difficulty is training workers to detect shoot borers or their eggs on the undersides of seedling leaves.

The most serious shoot borer is *Hypsipyla grandella*, which attacks through the terminal shoot (fig. 12-2). If outplanted (carrier) seedlings serve as breeding habitat in new plantings, virtually all terminal shoots are attacked within a year (*17*). The re
is multiple-branched stems that reduce the comn
cial worth of mature trees. A systemic insecticide
be applied in planting holes when seedlings are
planted; however, this control is costly and not
effective (*6*, *18*).

A second borer, *Diaprepes abbreviatus* (the sug
cane stalk borer) attacks both lateral roots and t
roots of mahogany seedlings and will work its way
the stem (fig. 12-3). Heavy infestations can kill en
seedling beds (*1*). Soil drench insecticides will con
this pest. In its adult form, the borer is a leafeater t
causes heavy defoliation.

12.4 Common Sucking Pests

*12.4.1 **Aphids.***—Aphids secrete honeydew t
serves as a growth medium for sooty mold, giv
plants a dark (sooty) appearance. Aphids attack te
scaly aphids have attacked kadam and *Gmel*
seedlings in Puerto Rico, but damage was not seric

*12.4.2 **Mealybugs.***—Mealybugs, related to aph
eat holes in leaves. They are not very visible un
reproduction begins and their numbers increa
Mealybugs seldom kill seedlings, but damage can
serious if seedlings lose large amounts of photos
thetic tissue.

*12.4.3 **Thrips.***—Kadam seedlings and trees
sustain heavy leaf damage by thrips (*Selenodthr*
rubrocinctus giard). If attack is widespread in
nursery, infected seedlings easily carry thrips to
field, resulting in the eventual death of some tre

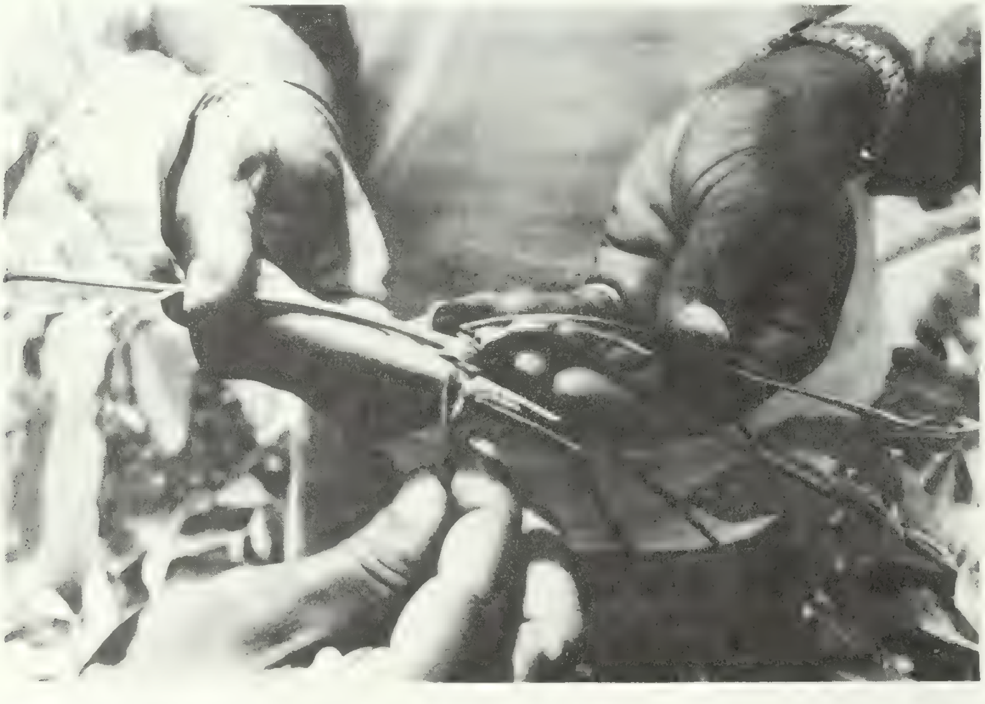

Figure 12-2.—*Short damage from shoot borer* (Hypsipyla grandella) *attack on mahogany in Puerto Rico nursery.*

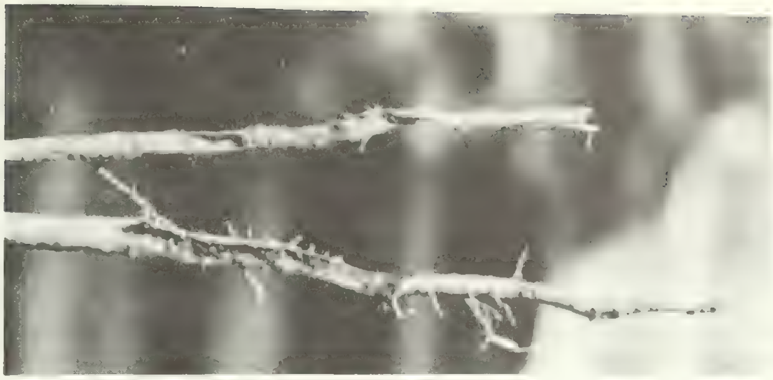

Figure 12-3.—*Damage to mahogany seedling roots from sugarcane stalk/root borer* (Diaprepes abbreviatus) *in Puerto Rico nursery.*

12.4.4 ***Scales and Mites.***—Scales range in color om green to brown, and their bodies are covered ith wax. Like aphids, scales are not very visible unl reproduction allows numbers to increase substanally (*23*). Mite damage occurs as small spots, usually n the undersurfaces of leaves. Mites have eight legs ather than six as do true insects. Spider mite attacks re known for pine seedlings and older trees in Jaaica and naturally regenerated seedlings in Puerto ico (*1*). As long as seedlings are otherwise healthy, ots and yellowish foliage symptoms will gradually isappear.

2.5 Larger Pests

12.5.1 ***Spiders.***—Spider damage was observed in 974 on *P. caribaea* seedlings planted on Vieques, a mall island southeast of Puerto Rico (ITF, unpubshed data). The unidentified spiders spun webs round the terminal and side shoots of the seedlings nd laid eggs inside the nests. Death of some shoots ccurred; it was not determined whether death was aused by physical (strangling) or chemical means. n insecticide such as Spectracide can be sprayed to ill spiders that are damaging seedlings.

12.5.2 ***Birds.***—Special efforts are needed to protect ewly germinated seedlings from birds (*2*). They eat eeds that are partly exposed in germination trays or hat are easily scratched from seedbeds. They disturb ot medium while looking for insect larvae and cutorms (*14*). Birds also eat exposed seeds before cotyleons emerge. If this happens, seedlings generally die ecause the apical meristem is also eaten along with he seedcoat. A flock of birds can easily eat several housand seeds per day.

Although repellents (with stickers) are available to ontrol feeding on seeds by birds, the best method is to ompletely enclose germination trays and seedbeds ith a box frame covered with saran until all seeds ave germinated and seedcoats are thrown (fig. 5-2). uch control is impractical for large, direct-seeded seedbeds where repellents must be placed on seeds before they are sown. Large shade houses are the most effective way to keep birds away.

Where bird populations are low, straw or other mulches are used to protect seeded bare-root beds. However, large numbers of birds may feed heavily on mulched seedbeds. For some hardwood species like mahogany, seeds are not too palatable to birds or are so small (kadam and eucalyptus) that birds do not eat them. Birds do not eat seeds of species such as teak because the seedcoat is too hard or the seed is too large.

12.5.3 ***Rats and Mice.***—Rats and mice can be serious problems if direct-seeding is used. Basically, the same procedure mentioned above for birds is also used to protect seeds from rodents. Because saran shade screens are easily chewed through, they are reinforced with small mesh (6 mm) metal screening at the sides. Seed repellents are also effective controls against rats and mice. Appendix 12 (table A12-3) lists the repellents currently available.

Repellents must be used in conjunction with a sticker. The function of the sticker is to hold the repellent on the seedcoat during germination. Neither sticker nor repellent must interfere with germination.

12.6 Diseases

12.6.1 ***Damping-Off.***—Damping-off is common throughout most areas of the world and kills seedlings of all species (*15*). In forest nurseries, it is usually most severe among conifer seedlings. Two types may occur: 1) preemergence damping-off where pathogenic fungi attack and destroy seeds before hypocotyl emergence or attack seedlings before they have emerged from the soil and 2) postemergence damping-off where fungi attack seedlings shortly after they have emerged from the soil or germination medium. Postemergence fungi attack seedlings at or slightly above the root collar, causing seedlings to wilt and fall. Attack can be rapid, with entire seedbeds being affected within 24 hours. Postemergence damping-off is identified by a small dark-colored ring-like growth around the lower stem.

Cytological studies have shown that the pathogenic fungi quickly spread throughout stem and root tissue. Thus, once the attack has begun, affected seedlings cannot be saved (*7*, *8*, *11*, *12*, *19*, *20*).

Effective controls are: sterilizing seedbeds; avoiding excess moisture, temperature, and humidity in germination trays; avoiding excess nutrients such as phosphorus and nitrogen in seedbeds; and maintaining acidity of germination medium at a low level, around pH 5.0. Spores of most pathogenic fungi survive for many years in soil. Steam and methyl bromide sterilization are the best treatments for soil or germination medium. An alternate method is drenching with a formalin (2 percent solution in water) mixture. About 2 weeks before sowing, beds are saturated with about 4 liters of the formalin solution per square meter of bed and then covered with a dark polyethylene sheet. After 1 week the polyethlene sheet is removed and the bed material is turned or plowed. After 1 day of aeration, beds can be sown with seeds or transplants can be lined-out.

Once damping-off has occurred in a seedbed, germination medium should be removed if it cannot be sterilized in place. Fresh, sterilized germination medium should be used. Table 12-1 lists other effective disease control treatments.

12.6.2 Seedling Needle Blight.—This disease is sometimes found on pine seedlings; it is usually more prevalent at a late growth stage, such as in plantations (*9*). In Malaysia, weekly spraying with Daconil 2787 and Phelam gave the best control over needle blight caused by *Colletotrichum floeosporioides* in the nursery. Phelam, however, should not be used because it is reportedly toxic to mammals. Captan, ferbam, Polyram Combi, Cobosx, and Dieldrex 15 provided less protection than Daconil 2787. *Cylindrocladium macrosporum* and *C. pteridis* have also attacked *P. caribaea* and *P. oocarpa* in Malaysia.

12.6.3 Brown Needle Disease.—This disease has occurred in Puerto Rico and in Malaysia on *P. caribaea*. The causative agent is *Cercospora pini-densiflora*. In India, *C. pini-densiflora* was controlled by a 2-week spraying with a copper sulfate (bordeaux solution) based fungicide. Disease symptoms appear similar to those of needle blight, although the infection agents are different. Needle blight disease does not always lead to death, but once a seedling is infected with this disease, death invariably occurs.

12.6.4 Purple Foliage.—Pine seedlings often develop purple foliage while in the nursery. Though no disease organism has been identified, mild attack by a disease cannot be entirely ruled out. Although severe phosphorus deficiency is indicated by purple needles, phosphorus deficiency is not expected in we fertilized seedbeds. Trace element imbalances ma also be responsible for the purple foliage. No trea ment except monitoring the fertility level of seedbe or pot medium is recommended, since the purple col disappears once seedlings are outplanted.

12.6.5 Root Rot.—Seedlings often turn yello brown, with the succulent terminal flush falling ove Because affected seedlings appear to be under wat stress and look wilted, the usual reaction is to wat them. Closer inspection may show that the problem not a lack of water, but rather excess water that h caused root rot. The only proof is to lift some wilt seedlings and inspect their roots. If the taproot is n crotic and lateral roots are absent, then some form root rot probably exists (*4*). Sometimes the cortex the root collar is so rotten that it is stripped off seedlings are lifted from the soil.

The most effective control of root rot is to avo overwatering. However, if root rot does occur, th problem is probably compounded by poorly draine and poorly aerated pot medium or seedbeds. Pottin mixtures can be changed to provide better aeratio (Chap. 9).

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CHAPTER 13

13. NURSERY NUTRITION

Growth and performance of nursery stock is related to the nutrition of seedbed soil or container medium in which seedlings grow as well as the genetics and vigor of seeds sown. The fertility of nursery soil is predicted by both chemical and biological methods. If nutrient deficiencies exist, they can be corrected with organic or inorganic fertilizers that are short- or long-term acting. This chapter discusses nursery nutrition and several fertilizer alternatives. Appendix 13 gives practical guides for using and applying fertilizers.

13.1 Essential Elements

There is disagreement on which elements are truly essential for plant growth (*20*). Generally, carbon, hydrogen, and oxygen comprise the bulk of seedling weight. They are obtained directly from carbon dioxide (CO_2) and water (H_2O), which are not usually limiting except in waterlogged or very dry environments. Elements are traditionally called macroelements or microelements, depending on whether plants use greater or lesser quantities. Roots take up minerals principally from the solution or exchange complex of nursery soil or the container medium. Known functions of each element are summarized in table 13-1.

Each tree species, its varieties, and even individuals of a species have distinct nutrient requirements and uptake rates. Thus, table 13-1 is only a guide to the “basics” of plant nutrition. Elemental concentrations can vary by plant component (leaves, twigs, branches, fruits, and roots), age, position within the seedlings (top, center, or lower stem area), season (spring or fall), and climate (dry or wet) (*5*). Generalizations about seedling nutrition are therefore sometimes difficult to make.

13.2 Nutrient Deficiency Symptoms

Visual symptoms are usually the first signs that seedlings are growing abnormally (*20*). Common
symptoms are: severe stunting, delayed or abnorm
growth (twisted or missing needles), leaf discolorat
(bright yellow, purple, or red instead of green),
abnormal root growth. Symptoms develop when in
nal plant growth processes are interrupted by lack
one or more elements and by the organic metabol
that subsequently accumulate.

Published color pictures show deficiency sympto
for several temperate (*19*) but few tropical (*22*) s
cies. Lack of one element can cause divergent sym
toms in different species. Also, similar symptoms m
be caused by deficiencies of different elements (e
general chlorosis by lack of either N or S).

Some symptoms are caused by multiple nutri
deficiencies; others are not nutrient related at all.
example, if seedlings turn yellow, root systems
checked first to see whether overwatering has redu
aeration, thus killing roots and blocking nutrient a
water uptake. When deficiency symptoms appear,
reparable damage has probably occurred in shoot
root tissue. Though we recognize the limitations
trouble shooting nutrient deficiencies, a generali
“key” to visual symptoms is given in table 13-2.

Table 13-1.—*Function of major and minor elements in nursery nutrition*[1]

Element	Role in seedling nutrition
	Macronutrients
N (nitrogen)	Essential part of chlorophyll and proteins; fosters vegetative growth.
P (phosphorus)	Promotes root growth and stem strength; important in all energy transfers within plants.
K (potassium)	Promotes starch and sugar formation, root growth, resistance, shoot strength, and plant vigor.
Ca (calcium)	Enhances N uptake, cell elongation, and development of meristematic tissues.
Mg (magnesium)	Major constituent of chlorophyll in plants; important in P metabolism and enzyme activation.
S (sulfur)	Essential for synthesis of S-containing amino acids and nitrogen fixation by legumes.
	Micronutrients
Fe (iron)	Important in chlorophyll production and enzyme activation.
Mn (manganese)	Activates enzymes regulating carbohydrate metabolism and essential for photochemical (Hill) reaction.
Cu (copper)	Metal activator for several enzymes and possibly light reaction in plants.
Zn (zinc)	Metal activator of enzymes.
B (boron)	Responsible for several regulator mechanisms in many plants, including sugar translocation across cell membranes and oxidation processes.
Mo (molybdenum)	Required for N-fixation in legumes and nitrate reduction in nonlegumes.

[1] Sources: (*9*), (*20*).

13.3 Foliage (Tissue) Sampling

Foliage, tissue, or plant analysis is used ope
tionally to determine seedling nutritional status
fore deficiency symptoms appear (*12*, *14*, *24*). T
rationale for this method is: if adequate elemen
concentrations exist for good growth in plant folia
then concentrations of the same element are adequ
in the soil. Through nursery and field fertilizer c
bration trials, one determines “critical” concent
tions, i.e., elemental levels at which plant grow
drops below optimum. Excess amounts of certain e
ments such as Fe, B, or Mn are toxic to plants. U
ally, however, plants absorb excess nutrients witho
harmful effects. Good plant growth with nutrient l
els beyond those normally needed is called “luxu
consumption” (*5*).

In temperate areas, foliage is sampled at first ha
ening, usually in late summer when nutrient conc
trations are less variable than at other times in t
growing season. Except for a few instances, montl
and seasonal fluctuations are not known for tropi
tree species that grow all year long (table 13-3). Ho
ever, sampling can be done one-third and two-thi
through the period that seedlings are held in the nu
ery before outplanting (e.g., for seedlings held
weeks, then sample at 1/3 of 24 = 8 and 2/3 of 24 =
weeks).

Best results are normally obtained by sampling m
ture, fully developed leaves or fully elongated needl
If seedlings lack secondary needles, dry and grind
of the above ground tissues of several seedlings.
secondary needles are present, dry and grind t
needles only, after collecting fascicles from a co

Table 13-2.—*Key to the classical symptoms of various nutrient deficiencies*[1]

Symptoms	Symptoms may be related to . .
a. The dominant symptom is chlorotic foliage (discoloration).	
b. Entire leaf blades are chlorotic.	
c. Only the lower leaves are chlorotic, followed by necrosis (tissue death) and leaf drop.	Nitrogen
cc. Leaves on all parts of plant are affected and often have a beige cast.	Sulfur
bb. Yellowing of leaves takes the form of interveinal chlorosis.	
c. Only older leaves exhibit interveinal chlorosis.	Magnesium
cc. Only younger leaves exhibit interveinal chlorosis.	Iron and/or manganese
d. This is the only symptom.	
dd. While younger leaves have interveinal chlorosis, the tips and lobes of leaves remain green, followed by veinal chlorosis and rapid, extensive necrosis of leaf blade	Copper
ddd. Young leaves are very small, sometimes missing leaf blades altogether, and internodes are short, giving a rosette appearance.	Zinc
aa. Leaf chlorosis is not the dominant symptom.	
b. Symptoms appear at base of plant.	
c. At first, leaves are dark green and smaller than normal. Later, purple pigment develops in older leaves.	Phosphorus
cc. Margins of older leaves burn or small necrotic spots appear on older leaf blades.	Potassium
bb. Symptoms appear at top of plant.	
c. Terminal buds die, giving rise to a witches'-broom.	Boron
cc. Margins of young leaves fail to form, sometimes yielding trap-leaves. Growing point ceases to develop, leaving a blunt end.	Calcium

[1] Adapted from material of P. Nelson, Horticulture Department, North Carolina State University, Raleigh.

site sample of many seedlings. Collections are best ade in the early morning, *before* seedlings begin nthesizing carbohydrates and utilizing nitrates ac-mulated at night.

Leaf petioles from large-leaved seedlings (e.g., from ak or mahoe) should not be included in the sample. tal analysis is performed on tissue samples, using ndard procedures (*6*, *7*).

Rapid or "quick tissue tests" on plant sap are some-nes used (*20*). Results, however, are not quantita-e and should not be substituted for diagnostic alyses. Sampling done in duplicate provides extra aterial for checking test results.

Foliage analysis interpretations must consider both vironment of the seedlings tested and their physio-gical state. Are seedlings growing vigorously or are ey stunted? Are there signs of above ground or be-w ground insect or disease attack? Is seedbed medium well aerated or is soil moisture excessive? Have climatic conditions before sampling been unusually moist or dry? Is soil pH value or salt content too high? For example, discolored and stunted seedlings with "high" tissue values for N, P, and K does not mean that these nutrients are present in adequate amounts. Poor growth, but seemingly adequate tissue nutrient levels, suggest that some other factor is limiting seedling growth, perhaps underground root borers (fig. 12-3).

Foliage analysis has two disadvantages. Calibration trials to establish high, low, medium, and critical levels for each element are costly and time consuming. Also, techniques and equipment needed for chemical analyses are rather sophisticated, requiring highly trained personnel. If facilities for agricultural foliage research exist, techniques are easily adapted for forest nursery diagnostic work.

Table 13-3.—*Mean foliage concentrations for forest tree species in Puerto Rico and elsewhere for comparison*

Foliage element concentrations	*Pinus caribaea* var. *hondurensis*[1]				*Eucalyptus deglupta*[2] (15 mo)	*Pinus elliotti*[3]	Conifers[4]	Hardw
	3 yr		4 yr					
	Normal	Foxtail	Normal	Foxtail				
N, %	0.98	1.25	0.92	1.16	0.64–2.04	0.98–2.16	1.00–1.10 (deficient)	1.00–4.0 (medi
P, %	0.08	0.12	0.09	0.10	0.10–0.69	0.12–0.43	0.10–0.30 (medium)	0.30–0.5 (medi
K, %	0.77	1.09	0.90	1.09	0.44–1.78	0.23–1.73	0.35 (deficient)	0.50–1.6 (medi
Ca, %	0.27	0.26	0.25	0.34	0.46–1.40	0.08–0.79	0.12–0.70 (medium)	0.30–2.3 (medi
Mg, %	0.08	0.10	0.10	0.13	0.13–0.42	0.08–0.26	....	0.08–0.4 (medi
Na, %	0.14	0.17	0.11	0.18	....	....	....	....
Mn, p/m	491	572	479	724	8–270	....	100-5,000 (medium)	
Cu, p/m	5.1	5.9	4.8	4.7	2.0–6.4	....	4-12 (medium)	
Zn, p/m	30	37	29	38	6–49	....	10-125	
Fe, p/m	110	116	50	59	32–148	....	30-40	
B, p/m	12	15	12	12	15–84	....	10-100	
Al, p/m	493	469	410	557	....	....	....	....

Sources: [1](*10*), [2](*7*), [3](*11*), [4](*8*); data for p/m apply to both conifers and hardwoods.

13.4 Soil Tests

Soil tests *directly* determine the nutrient-supplying power of a soil. Methods require a knowledge of chemistry and laboratory instrumentation, usually found at a country's agricultural research station. Soil tests are usually better than foliage tests because they indicate a nursery soil's nutritional status and fertilizer needs *before* seeds are sown or seedlings are transplanted (*23*).

Other objectives of soil tests are:

- to maintain the fertility status of different nursery beds and
- to predict the response of beds to lime and fertilizer additions.

The nutrients of greatest interest are the amounts of cations (Ca, Mg, and K) and P. Organic matter content, pH value, and salt levels are also important.

The most critical part of soil testing is obtaining a representative sample. All areas that vary in appearance, slope, drainage, soil type, or past treatments should be sampled separately. In areas where fertilizers were previously applied in bands, samples should be taken between the bands. A single 0.5- to 1.0-kg sample consists of a composite of 10 to 20 tube cores or spade scrapings (fig. 13-1), usually taken to abou cm (normal seedling root depth). All sampling sh be done well ahead of scheduled sowing so that fe izer can be applied if needed.

Many different extracting solutions are used to termine soil nutrient concentrations or contents For permanent nurseries, the same extraction pr dures must be used from year-to-year to standar interpretations. Where no prior data exist for nurseries, soil test data should be taken and anal in a manner similar to that used for local or regi agricultural research. Data from crop trials are t used to determine interim fertility levels for nur soils. Fertility tests should be run on homem mixes to assure that all essential elements present in adequate quantities. Examples of soil tility standards for field nurseries are given in t 13-4.

13.5 Special Soil Problems: Acidity and Salt

Soil reaction or pH value is a measure of the deg of acidity or alkalinity of a soil. A scale of 0 to 1 used, with 7.0 as the neutral point (fig. 13-2). S

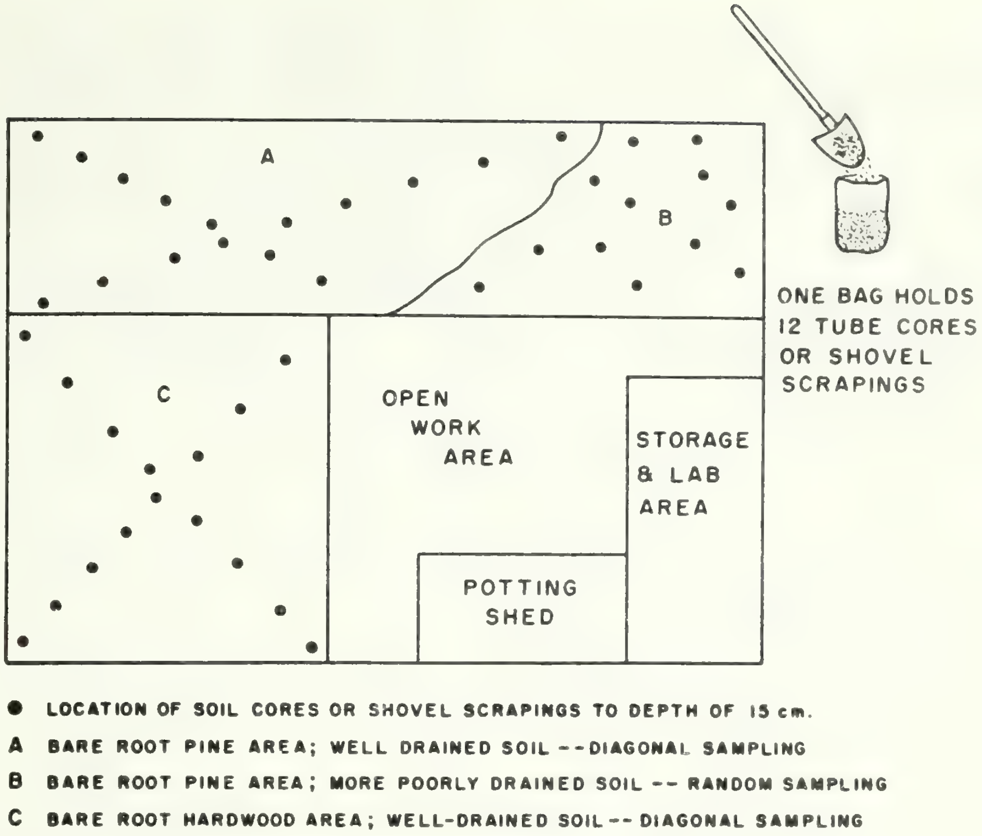
A
B
C
OPEN WORK AREA
STORAGE & LAB AREA
POTTING SHED
ONE BAG HOLDS 12 TUBE CORES OR SHOVEL SCRAPINGS
● LOCATION OF SOIL CORES OR SHOVEL SCRAPINGS TO DEPTH OF 15 cm.
A BARE ROOT PINE AREA; WELL DRAINED SOIL --DIAGONAL SAMPLING
B BARE ROOT PINE AREA; MORE POORLY DRAINED SOIL -- RANDOM SAMPLING
C BARE ROOT HARDWOOD AREA; WELL-DRAINED SOIL -- DIAGONAL SAMPLING

Figure 13-1.—*Collecting nursery soil samples for chemical and physical analyses. Take 10 to 20 tube cores or shovel scrapings for each distinct soil type, drainage area, and/or bed area devoted to different species. All soil samples are usually taken to a depth of 15 cm. They are bulked (mixed) into one composite sample that is eventually analyzed in a soil laboratory. In the example above, at least three samples are taken, one each from areas A, B, and C. If size of an area is 1 ha or greater, divide it into smaller divisions, with a composite sample taken from each division. For uniform areas, criss-cross sampling (areas A and C) is easiest, whereas random or zig-zag sampling (area B) is best for areas with high soil variability.*

Table 13-4.—*General field soil fertility standards used for southern pine (A) and commercial woody plant (B) nurseries in the United States*

Soil property	Major soil types					
	Sands to loamy sands		Loamy sands to sandy loams		Silt loams to loams	
	A[1]	B[2]	A[1]	B[2]	A[1]	B[2]
Organic matter, %	1.5	....	2.0	....	>3.0	....
N, %	0.07	....	0.10	....	0.15	....
pH	5.3–5.8	....	5.3–5.8	....	5.3–5.8	....
P, kg/ha	55–110	15–30	85–110	30–40	85–140	40–80
K, kg/ha	85–140	70–110	140–200	110–170	170–280	170–225
Ca, kg/ha	450–670	670–900	670–1,000	1,120–1,800	>1,000	2,240–4,480
Mg, kg/ha	55–65	130	65–100	270	>100	540

Sources: [1](*11*), [2](*3*).

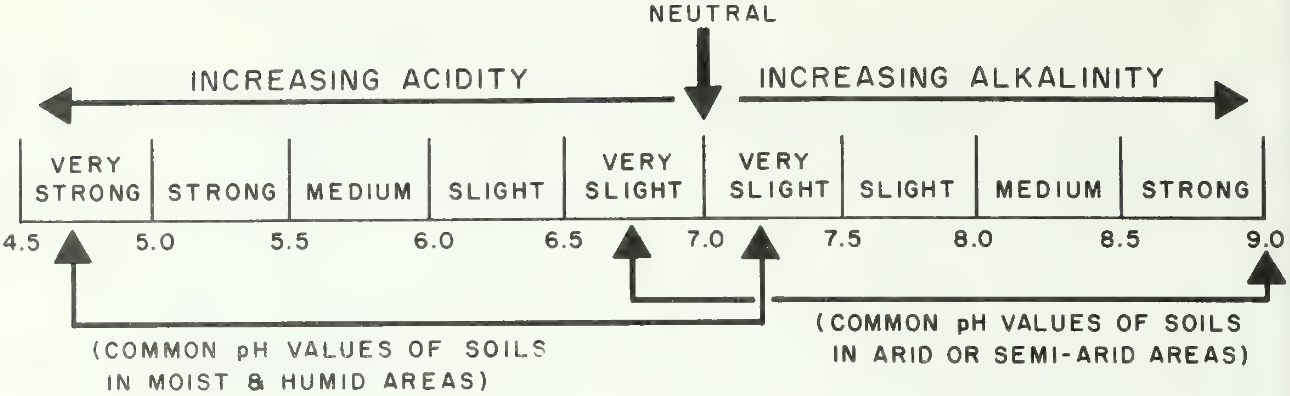

Figure 13-2.—*Soil pH values and their relationship to acidity and alkalinity. Taken from (9).*

with pH values *less than* 7 are *acid*, and those with values *greater than* pH 7 are *alkaline*. The pH scale is a logarithmic one; thus, an increase or decrease of one pH unit means a tenfold change in acidity or alkalinity. For example, a soil with pH 5.0 is 10 times more acidic than a soil with pH 6.0, but a soil with pH 4.0 is *100 times more acidic* than a soil with pH 6.0 (*9*).

Soil acidity has a strong influence on nutrient availability in nursery soils or pot mixes. For example, macronutrients are readily available within a range of pH 6.0 to 8.0, but availability decreases rapidly as pH value decreases (*21*). On the other hand, Fe and Zn are almost unavailable if the soil pH is over 7.5 (fig. 13-3). Pine seedlings grow best in acid soils ranging from pH 4.5 to 6.0. In soils with high pH values (>7.0), pine seedlings will develop a deep yellow color because Fe is "unavailable" to the seedlings.

Where the soil is too acidic for plant growth, pH values can be raised by applying limestone. Amounts of limestone needed will vary according to the degree of pH change desired, existing soil texture, organic matter content, and form of limestone used. The amounts of limestone needed to raise soil pH to 6.5 for different textured soils having varying initial pH values is given in table 13-5. When the pH value is too high, it can be lowered by applying acid-forming fertilizers (table 13-6).

Table 13-5.—*Approximate amounts of finely ground pure limes (kg/ha) needed to change acidity of an 18-cm lay soil*[1]

Soil type	pH change	
	4.5 to 5.5	5.5 to
Sand or loamy sand	600	900
Sandy loam	1,100	1,550
Loam	1,700	2,200
Silt loam	2,700	3,100
Clay loam	3,350	4,200

[1]Values listed are "approximate" because amounts needed f given change are highly influenced by actual particle size and rity of lime used as well as active and reserve acidity of the being limed. Source: (*9*).

Soluble salts should be monitored regularly. Ma species will not tolerate saline conditions and may b injured by high levels of Na, B, and chlorides found i irrigation water. Fertilizer components can a break down into soluble salts that accumulate i nursery soil or potting medium.

Salt levels can be measured with a solu-bridge. sample of soil is mixed with distilled water, and t solution is tested for its ability to conduct electrici Either a saturated paste or distilled water/soil di tion methods (in 2:1 or 5:1 ratios) are used. Interpre

Table 13-6.—*Ways of lowering soil pH value with acid-forming fertilizers*[1]

Fertilizer	Pct N in fertilizer	Kg of pure limestone needed to counteract acidity produced per —	
		45.4 kg of fertilizer	0.45 kg of N[2]
Ammonium nitrate	33–34	27.2	0.8
Ammonium sulfate	20–31	49.9	2.4
Ammonium phosphate	16	39.9	2.4
Urea	45–46	38.1	0.8
Mono-ammonium phosphate	11	26.3	2.4
Di-ammonium phosphate	21	33.6	1.6

[1]Source (*9*).

[2]Values in this column are most important for judging fertilizer effectiveness: ammonium sulfate, ammonium phosphate, and mono-ammonium phosphate are three times as acid-forming as ammonium nitrate and urea.

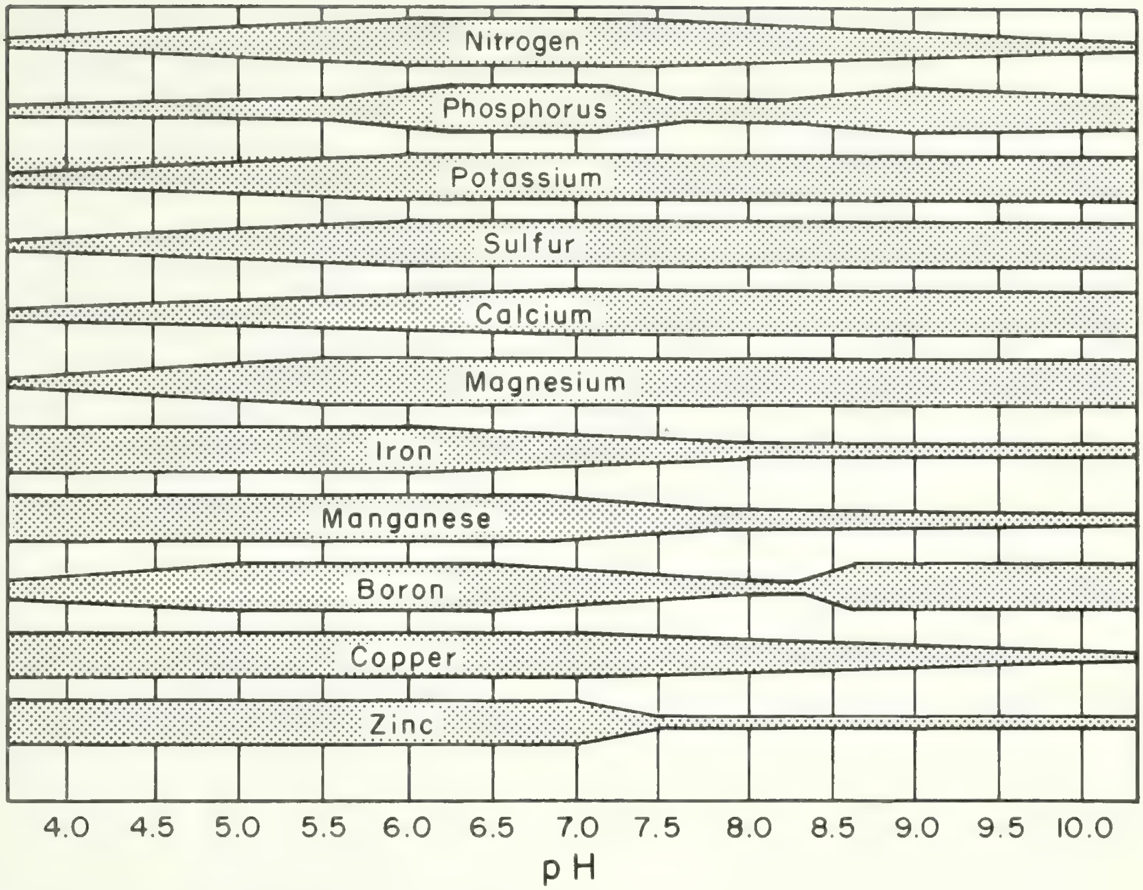

Figure 13-3.—*Relationship of soil acidity and alkalinity to nutrient availability. Taken from (9).*

ns of solu-bridge data are given in table 13-7. Irri-tion water can also be tested for excess salts using milar methods. For nursery production, irrigation ater should have less than 250 micromhos/cm (*9*).

.6 Fertilizers

Fertilizers are classified as inorganic or organic and tural or synthetic (table 13-8). They can be single- multi-element in composition and are available in y and liquid forms. Complete fertilizers have the ree primary elements, expressed as percentages of emental N, P_2O_5 (phosphate), and K_2O (potash). us, a label with 5-10-5 means 5% N, 10% P_2O_5, and K_2O. In 1 kg this is 50 g of N, 100 g of P_2O_5, and g of K_2O. Inorganic fertilizers may have acid, alka-ne, or neutral reactions (table 13-9). Natural organic rtilizers or composts vary greatly in amounts of N, and K (*13*) (table 13-10).

Three alternatives for applying fertilizers are:

mix dry fertilizers directly with the growing medium;
put soluble fertilizer solutions on the soil; or
formulate and use dry fertilizer mixes and soluble solutions on site.

Each alternative has distinct advantages and disadvantages, depending on whether field- or container-grown seedlings are produced.

13.6.1 Mixing Fertilizers With Growing Medium.—This alternative is commonly used for dry (commercial) fertilizers applied before sowing or transplanting. The fertilizer is placed in bags with pot medium or is incorporated with soil of bare-root beds. Mix proportions depend on whether soil test values are high or low and on actual fertilizer proportions available in the mixes. Import restrictions may limit availability of fertilizer mixes in some countries.

Dry fertilizers can also be broadcast by hand or applied by machine with drills on larger areas or in bands between seedling rows. "Top dressing" alternatives are not suitable for containerized nurseries (*19*). Disadvantages are the trouble and high cost of mixing different fertilizers and pot medium for different stages of seedling growth (e.g., rapid growth phase vs. hardening-off phase) and the tendency of most slow-release dry fertilizers to raise medium pH value. Large traditional nurseries still incorporate fertilizers with pot mix (*15*).

13.6.2 Using Soluble Fertilizer Mixes.—This alternative is ideal for small nurseries needing minimal

Table 13-7.—*Soluble salt levels in soils and irrigation water and their influence on plant growth as determined by electrical conductivity*[1]

Electrical conductivity		
Millimhos/cm	Micromhos/cm	Diagnosis
Soils		
Less than 2	Less than 2,000	No adverse effect.
2	2,000	Yields of some salt sensitive crops are affected.
Below 8	Below 8,000	Only moderately salt tolerant crops can be grown.
8–16	8,000–16,000	Only salt tolerant crops can be grown.
Above 16	Above 16,000	No profitable cropping possible.
Irrigation water		
0.1–0.25	100–250	Low salinity: safe to use on practically all crops and soils, but some leaching is needed to keep salts moving downward; problems may develop on poorly drained soils.
0.25–0.75	250–750	Medium salinity: medium salt tolerant crops are needed; soils must be relatively permeable.
0.75–2.25	750–2,250	High salinity: only for salt tolerant crops; adequate subsurface drainage is essential, as is sufficient water for leaching out excess salts.
Above 2.25	Above 2,250	Very high salinity: should not be used for irrigation except under certain ideal conditions (i.e., permeable soil and/or tile drains for good drainage, high water rates for good leaching).

[1] Source: (*9*).

Table 13-8.—*Chemical and physical properties of fertilizers*[1]

Chemical properties	Physical properties
A. State:	A. State:
1. Organic:	1. Dry:
(a) Natural	(a) Pulverized
(b) Synthetic	(b) Granular (prills)
	(c) Tablet
	(d) Packet
	(e) Encapsulated
2. Inorganic:	2. Liquid:
(a) Natural	(a) Water-soluble
(b) Synthetic	(b) Suspension
B. Element:	B. Release rate:
1. Single	1. Rapid
2. Double	2. Slow (controlled)
3. Triple (complete)	
4. Multi	
C. Long-term effect on soil acidity:	
1. Acidic (lowers pH value)	
2. Neutral	
3. Basic (raises pH value)	

[1] Source: (*3*).

ble 13-9.—*Element content, reaction, and solubility of common fertilizer chemicals*[1]

Common fertilizer name	Chemical formula	Fraction of element in compound (× 100 = %)								
		(NO_3) N	(NH_4) N	P	K	S	Ca	Mg	Long-term reaction[2]	Solubility[2]
tassium nitrate	KNO_3	0.139			0.386					
nmonium nitrate	NH_4NO_3	0.175	0.175						Acid	High
lcium nitrate	$Ca(NO_3)_2 \cdot 4H_2O$	0.119					0.169		Base	Medium
ammonium phosphate	$(NH_4)_2HPO_4$		0.212	0.235					Acid	Low
nmonium sulfate	$(NH_4)_2SO_4$		0.212			0.242			Very acid	High
tric acid	HNO_3	0.222							Very acid	High
thophosphoric acid	H_3PO_4			0.316						
tassium metaphosphate	KPO_3			0.228	0.287					
ncentrated superphosphate	$Ca(H_2PO_4)_2 \cdot H_2O$			0.246			0.159			
tassium carbonate	K_2CO_3				0.565					
lcium-magnesium carbonate (dolomite)	$CaCO_3 \cdot MgCO_3$						0.217	0.130		
agnesium sulfate	$MgSO_4 \cdot 7H_2O$					0.130		0.097		
tassium sulfate	K_2SO_4				0.448	0.184				
lfuric acid	H_2SO_4					0.326				
eta phosphoric acid	$P_2O_5 \cdot H_2O$			0.437						
tassium oxide (potash)	K_2O				0.830					

[1] Adapted from (*19*).

[2] Missing data were not available.

Table 13-10.—*Average nutrient content of fresh animal manures before composting*[1]

Nutrient or element	Cattle	Chicken	Horse	Sheep	Swine
			Percent		
Nitrogen (N)	0.53	0.89	0.55	0.89	0.63
Phosphorus (P_2O_5)	0.29	0.48	0.27	0.48	0.46
Potassium (K_2O)	0.48	0.83	0.57	0.83	0.41
Calcium (Ca)	0.29	0.38	0.27	0.21	0.19
Magnesium (Mg)	0.11	0.13	0.11	0.13	0.03
Copper (Cu)	0.00079	0.0006	0.00079	0.00079	0.00016
Manganese (Mn)	0.003	0.003	0.003	0.003	0.0008
Zinc (Zn)	0.0016	0.0021	0.002	0.002	0.0006
Chlorine (Cl)	0.03	0.08	0.08	0.08	0.03
Sulfur (S)	0.036	0.06	0.036	0.06	0.03
Boron (B)	0.016	0.016	0.016	0.016	0.0005
Organic matter	16.74	30.70	27.06	30.70	15.50
Moisture	18.33	64.82	68.85	64.82	77.56
Ash	2.06	4.72	6.70	4.72	6.02

[1] Since moisture percentage of any manure is highly variable, indicated nutrient percentages are general values. Source: (*9*)

amounts of fertilizer or for very large nurseries having good irrigation equipment (*2*). Commercial powders or granules are dissolved in water, and solutions are applied to seedlings with hand-pump sprayers or are injected into irrigation systems. This method is adaptable to nurseries growing several species. However, what works in one location might not work well in another because of differences in local water quality, inherent chemical properties of nursery soils and pot medium, and existing environmental factors. Systems should be tested on small plots before they are used operationally.

Commercially formulated soluble fertilizers are easily prepared with minimal instructions or precautions. Some drawbacks can be: insufficient knowledge about the "carrier" or chemical compounds used to supply the nutrient ions; use is limited to the nutrient proportions available in the mixes; salts used as nutrient carriers can modify soil solution acidity, requiring a separate pH adjustment; and workers preparing solutions cannot easily compensate for Ca, Mg, or micronutrients that are naturally available in local water supplies, thus risking the possibility of adding excess salts.

13.6.3 Formulating Nutrient Solutions on Site.—This alternative involves making "homemade" fertilizer solutions to be applied by hand sprayers or injected into irrigation systems. Technical grade chemicals are added to water according to a formula adjusted for local water supplies and the species grown. Homemade solutions are not practical for small nurseries. However, they are very cost effective for large, highly mechanized container systems where managers have ready access to chemical compounds and need to tailor their fertilizers to particular crops, pot mixes, and water composition.

Disadvantages of homemade solutions are: the u must be trained in chemistry and be able to han hazardous materials carefully and safely; large sto of chemicals must be safely stored, identified, a weighed before mixing; opportunities for mixi errors are greatly increased over those encountered using premixed fertilizers; and, when optimum c centrations are unknown, fine tuning of the formu tion is time consuming and requires technical exp tise.

Appendix 13 gives hints and methods for mixi commercial fertilizers. Other important consid ations for correct fertilizer application are timing, i not too wet or too dry (*18*); interaction effects betwe species and fertilizers (*16*); type of soil being fert ized, i.e., not all soils respond to fertilizer additic (*17*); and age/health status of seedlings (*4*) being f tilized.

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CHAPTER 14

14. NURSERY EXPERIMENTATION

14.1 Planning the Experiment

Experiments are important in permanent nurseries because they produce information for managerial or technical guidelines (*18*). For example, experiments can indicate whether top dressed granular or liquid N fertilizer is best for a particular bare-root nursery in a wet climate. Experiments may also indicate which of several locally available postemergent herbicides gives the longest coverage in comparison with traditional hand weeding.

Experimentation is often excluded from nursery and reforestation efforts because its purpose is misunderstood or because it is confused with statistics. *Experimentation is the systematic observation, classification, and analysis of facts and data*; it emphasizes the *why* and *how* of what is done. Statistics, on the other hand, are mathematical measures that describe *organized* raw experimental data. The most commonly used measures are the *mean*, *standard deviation*, *variance*, and *coefficient of variation*.

Commonly used statistical measures are given in table 14-1. A hypothetical experiment is explained here to illustrate how experimentation is important for effective decision making in reforestation projects.

14.1.1 Traits Assessed.—Experiments can be done in the nursery or in the field. Many measurement traits or variables can be measured or assessed. Examples (*2*, *5*) are:

Seed/Seedling Traits

- Average seed weight and size
- Mean germination time for seeds
- Percentage of seeds germinated within stated periods of time
- Number of cotyledons
- Seedling height in centimeters, at stated periods of time or before lifting
- Seedling root collar diameter in millimeters, using calipers
- Seedling survival, in percent, at different growth stages of nursery

Container/Irrigation Traits

- Container volumes in tapered and non-tapered cavities and their influence on root development
- Potting mix proportions of 20, 40, and 60 percent peat and their influence on seedling growth
- Hand- and mechanically-seeded containers and their effects on seedling growth
- Overhead versus side sprinklers and their effects on reducing seedling mortality from persistent drip

In each instance, events or traits are recorded according to *previously formulated plans and designs* (*11*). In a few cases, unusual phenomena are also reported (*15*, *17*).

14.1.2 Sources of Variation.—Nurseries genera have less environmental variation than do field sit Nurseries occupy small areas within which skil researchers can control light, temperature, soil mo ture, soil nutrients, and soil aeration more easily th on larger field sites. Small amounts of plant materi used in nursery research are also less variable th are larger amounts of field planted materials. Exc tions occur when individual plants are used as tre ments. In such cases, plant-to-plant variation, part ularly in yield, may be great. Averaging many pla together to obtain treatment values avoids excess variation (e.g., grinding up 10 seedlings—not 1— treatment replication to obtain shoot/root ratios seedlings grown in one type of container having ferent pot volumes).

Investigators studying nursery and greenhouse perimental designs (*4*, *6*, *8*) have identified seve sources of variation:

- temperature differences around benches caused steam pipes and proximity to doors, ventilato and exhaust fans;
- shading effects from nursery structures and s rounding trees;
- moisture differentials caused by air currents (dri and clogged irrigation nozzles;
- non-uniformity of physical and chemical propert of pot medium caused by using medium prepar in different production runs; and
- changing light intensity and duration as growi seasons change.

Properly designed research trials avoid such var tion whenever possible or at least account for it adequate replication.

14.1.3 Experimental Procedures.—An overall search plan is essential when conducting expe ments. It should always answer: Who? Why? Wh Where? When? How? and How much?

The first step is outlining the objectives and qu tions to be answered. Always *restrict* objectives t few simple ones. Written objectives and a writt work plan are critical for maintaining longer tri that continue after their originator has left.

Consider a postemergent herbicide trial to cont weeds in bare-root pine seedbeds. Two importa questions are: which herbicide controls weeds for t longest time without reapplication? Are the her cides used non-toxic for the pine species tested? Ob ously, all herbicides and pine species cannot be teste How, then, does one limit the scope of the propos herbicide trial?

14.1.3.1 Restricting Experiment Objectives.—F stricting the objectives can be done by consideri data on herbicides from elsewhere, including local sults from agricultural or horticultural trials. Lo product availability can limit the herbicides event ally chosen for testing. After reviewing available

Table 14-1.—*Summary statistics for two data sets*

Statistic[1]	Data set I			Data set II		
	A	B	C	A_1	B_1	C_1
	8	5	1	8	5	1
	8	6	2	9	7	5
	9	8	5	9	9	8
	10	10	10	10	10	10
	11	12	15	10	11	12
	12	14	18	11	13	15
	12	15	19	12	15	19
Sum	70	70	70	70	70	70
Mean ($\bar{x}$)	10	10	10	10	10	10
Standard deviation (s)	1.7	3.9	7.5	1.3	3.4	6.1
Variance (s^2)	2.9	15.2	56.2	1.7	11.6	37.2
Coefficient of variation (CV-%)	17	39	75	13	34	61

[1] $\bar{x}$—The sum of individual observations divided by total number (n) of observations in a sample or set of values. Each of the six data groups has an n of 7 (observations); thus, each of the six sums is divided by 7 to obtain the mean.

s—A summarization unit for interpreting whether individual observations are clustered around or spread away from the mean. Symbolically it is calculated:

For group A of Data Set I:

$$s = \sqrt{\frac{\Sigma X^2 - \frac{(\Sigma X)^2}{n}}{n - 1}} \quad \frac{(8)^2 + (8)^2 + (9)^2 + (10)^2 + (11)^2 + (12)^2 + (12)^2 \quad \frac{(70)^2}{7}}{6} = 1.7$$

Group A has the *lowest* s in Data Set I; thus, observations in group A are very clustered around the mean of 10. Observations in Data Set II are all more clustered around their means, since the s of groups in Set II are all lower than those in Set I.

s^2—The square of s, or for data group A $(1.7)^2 = 2.9$. Statisticians use s^2 in analysis of variance for testing whether various treatments are significantly different from one another.

CV—It is used to evaluate results from several experiments measuring the same variable or trait. It is calculated:

$$CV = \frac{s}{x} \times 100\text{; for data group A,}$$

$$\frac{1.7}{10} \times 100 = 17.$$

In field experiments, CV values usually range from 15% to 50%; ≤15% in nursery experiments. If values are higher, there was too much variability in plant materials or site and nursery conditions, and the experiment must be done again.

ormation, one might decide to test different concen-rations of one locally available herbicide on the most romising pine species for reforestation. A concise tatement of experiment objectives would be:

"To determine the effect of three concentrations high, medium, low) of Goal herbicide and hand weed-ng (control) on weeds common in *P. caribaea* var. *ondurensis* bare-root seedbeds."

The traits assessed could be: coverage, or the maxi-num number of days between first and subsequent pplications needed to control (kill) weeds; seedling eight and root collar growth and survival at specific imes (2, 4, 6, and 8 months) in all beds where herbi-ides are applied and in hand-weeded control plots; nd seedling damage for all treatments and the con-rol over the duration of the experiment (i.e., some herbicide concentrations may be selectively toxic to certain pines and hardwood species).

14.1.3.2 Replicating the Experiment.—If a forestry company performs the experiment, it may conduct trials at two or more nurseries that it owns. This is beneficial because site conditions, particularly soil properties, may be dissimilar at the different sites. If herbicide coverage is related to site properties, the company should know this for long-term planning. *Replicating* the experiment is rather simple because the nursery locations are fixed in this example. In species adaptability trials, potential trial sites are almost infinite. Thus, in field research, it is usually difficult to choose (at random) small experimental areas that are typical of large areas that will be reforested.

A word of caution! Confounding two or more factors must be avoided. For example, if one conducts nursery experiments at two or more sites, major operational activities at each are assumed to be identical, whether they be sowing, undercutting, watering, or applying herbicides. Using different equipment and equipment operators having different levels of skill at two or more nurseries can influence seedling growth and development in significant ways that have nothing to do with herbicide treatments. When such differences are significant, confounding has occurred. Interpretation of research results is impossible when *unplanned* confounding occurs.

14.1.3.3 Randomly Assigning Treatments.—The last step is establishing the herbicide experiment in predetermined areas within the two nurseries. To avoid confounding, sites as uniform as possible are chosen at each nursery. Certain experimental designs take into account unidirectional or bidirectional site gradients that cannot be avoided (Sec. 14.2). Whatever the design chosen, all treatments (herbicides and control plots) are assigned randomly to all blocks. If not, some treatments will always appear next to others with possible confounding effects.

In summary, experimentation is an important, integral component of decision making in nursery projects. When conducting experiments, follow these three cardinal rules (the 3 R's) (*1*):

1. *Restrict* objectives to simple and manageable ones.
2. *Replicate* research plots on several sites if possible, and in several blocks at each site.
3. *Randomly assign* treatments to each experimental block at each site.

14.2 Experimental Design Considerations

14.2.1 Plot Shape.—Regular, compact experimental blocks have less microsite variation and are preferred over irregular shaped ones (fig. 14-1). When known moisture or other variation exists at a field site, place the long side of blocks *parallel* to the gradient (fig. 14-2). Sometimes, outside factors will dictate block shape and orientation, e.g., location of nursery roads and buildings (fig. 14-3). Making blocks or plots a convenient portion of a hectare (e.g., 0.01 or 0.02) simplifies converting raw data to a whole hectare basis.

14.2.2 Plot Size.—Optimum plot size depends on several factors, including available land, numbers of seedlings tested (i.e., some may be sacrificed or lost), seedbed spacing or container cavity density, and experiment duration. For example, nursery trials assessing hypocotyl color and chlorophyll content of primary and secondary needles require many seedlings because traits are highly variable (*13*, *14*). Conversely, if only mean seedling height and root collar diameter are assessed at different phases of nursery development, fewer seedlings and smaller plot sizes are used (*16*).

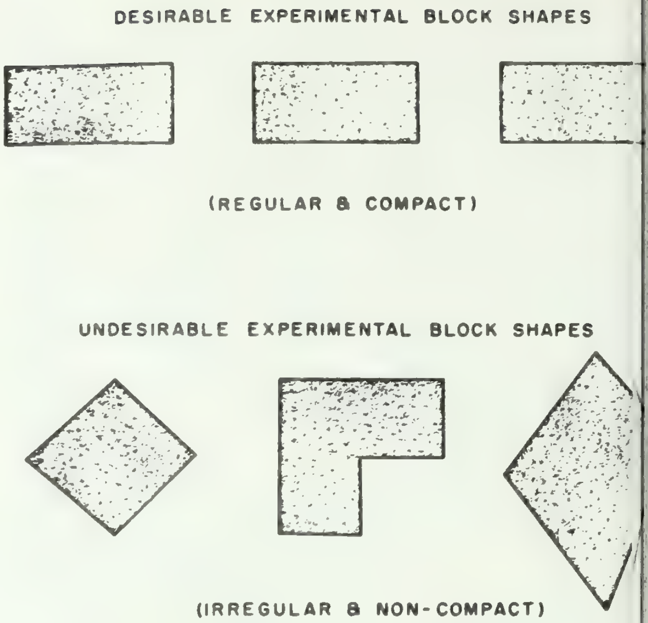
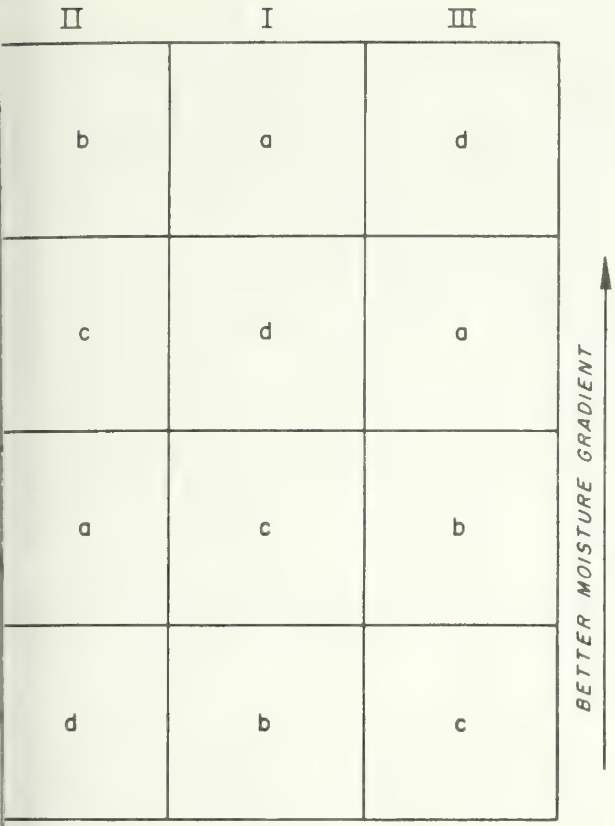

DESIRABLE EXPERIMENTAL BLOCK SHAPES
(REGULAR & COMPACT)
UNDESIRABLE EXPERIMENTAL BLOCK SHAPES
(IRREGULAR & NON-COMPACT)

Figure 14-1.—*Desirable and undesirable plot shapes for forestry experimentation.*

14.2.3 Border, Surround, or Edge Rows.—Edges of seedbeds are more exposed to light, wind, and nutrients (excluding container cavities) than are interior rows. Thus, seedlings (or grasses in fallow studies) in edge rows are not assessed in nursery trials because estimates of height growth and other traits may be biased, upwards or downwards, from estimates of interior seedlings (*10*). Leaving out one or more edge rows, depending on seedling density and plant material availability, is common for nursery experiments.

14.2.4 Number of Replications.—Fewer replications (blocks) are needed in a nursery than in field trials (Sec. 14.1.2). Two or three replications are the minimum number for most nursery experiments; four to five replications are the minimum for field trials and nursery experiments where there is a large variation in sites or plant materials. When nursery studies are outplanted, the same replication and randomization scheme should be followed.

14.2.5 Experimental Designs.—The four most commonly used experimental designs in nursery research are described below, including discussion of when a particular design is appropriate and the assumptions involved, its advantage over other designs, its limitations and restrictions, and a practical example for its use. Basic texts on statistics (*3*, *7*, *9*, [illegible]) contain instructions on calculating sums of squares and error mean squares for analysis of variance and multiple comparison tests of treatment means. Factorial experiments are omitted because they are more



II, III — EXPERIMENTAL BLOCKS
a — LOW DOSAGE HERBICIDE
b — MEDIUM DOSAGE HERBICIDE
c — HIGH DOSAGE HERBICIDE
d — CONTROL (I.E., HAND WEEDING)

gure 14-2.—*Appropriate randomized complete block design for nursery experiments where site gradient is in one direction.*

mplicated in theory, implementation, and analysis.
14.2.5.1 Completely Random.—When experimen-
l conditions and materials are quite uniform, a com-
etely random design is used. It is simple to set up
d analyze data obtained. There are no restrictions
the number of replications and treatments. In the
ample shown in figure 14-4, four fungicides (A, B,
and D) are tested to control damping-off in germi-
ting trays. Sixteen trays with seeds are prepared
d randomly assigned to a particular treatment. The
ial lasts as long as normal germination continues.
is design assumes that all trays have the same
rminating medium, are seeded with the same
nount of seeds from similar lots (having equal per-
ntages of germination), and are watered and tended
ually. Also, it assumes that there are no changes in
mperature, light, etc., from bench A to bench D.
14.2.5.2 Randomized Complete Blocks.—When
riation exists in one direction, the randomized com-
ete block design requires fewer replications and is
ore precise than a completely random design. Ad-

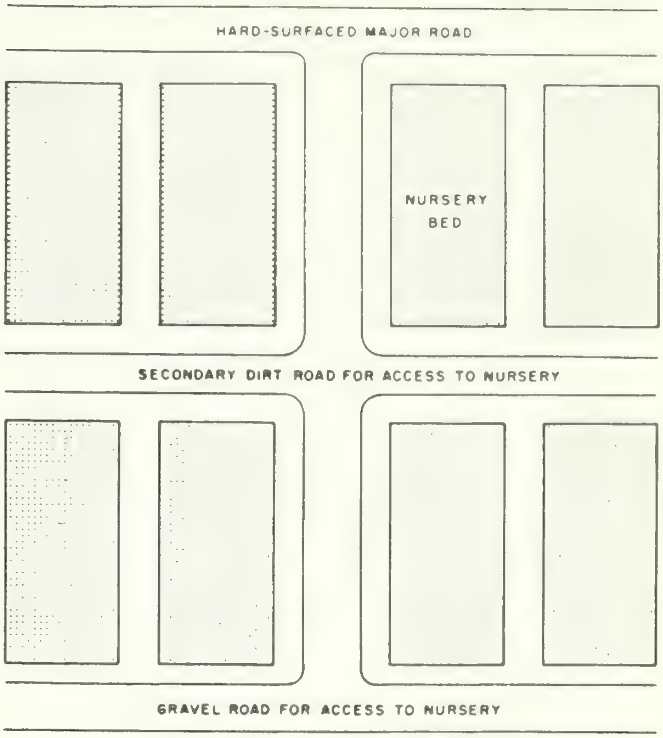
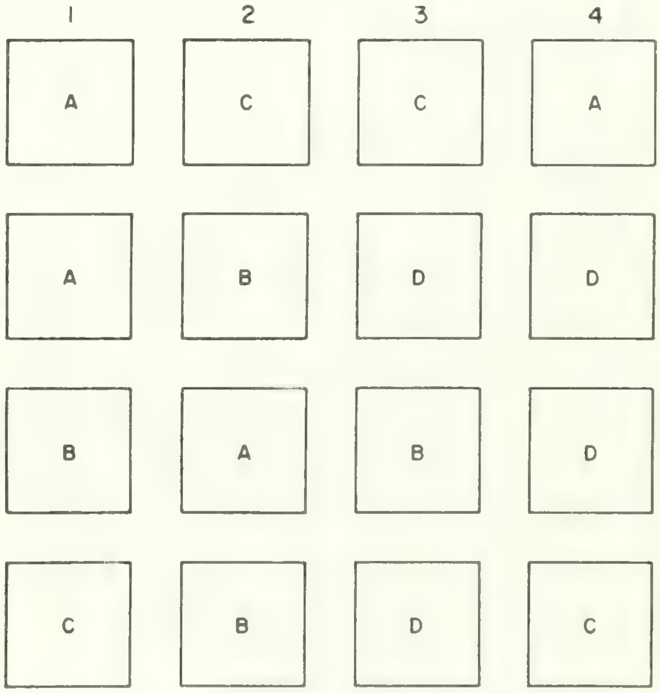

HARD-SURFACED MAJOR ROAD
NURSERY BED
SECONDARY DIRT ROAD FOR ACCESS TO NURSERY
GRAVEL ROAD FOR ACCESS TO NURSERY

Figure 14-3.—*Outplant design for nursery site that is affected by physical constraints that place four beds on east and four beds on west side of major access road to nursery.*



1, 2, 3, 4 — NURSERY BENCHES
A, B, C, D — FOUR FUNGICIDES (ONE PER EACH SEED-GERMINATION FLAT)

Figure 14-4.—*Completely random experimental design for comparing effects of four fungicides (A, B, C, and D) on controlling damping-off in pine germination flats.*

vantages of randomized complete blocks are: simple installation and easy data analysis, even when there are missing or lost plots. The design is not appropriate when: within-block variation is great, blocks interact with treatments, or the number of treatments is large. The major restriction is that the same treatments are applied in each block.

Figure 14-2 shows a randomized complete block layout for the herbicide trial mentioned in Section 14.1.3.1. Long sides of Blocks I, II, and III are placed parallel to a known moisture gradient. Within each block, the four treatments are randomly assigned. Note that the "control" is a hand-weeded plot, not a no-weeded plot. If a plot is not weeded, weeds in it can invade adjacent plots, limiting the effect of herbicides.

Bed preparation techniques and tending operations, particularly watering, are assumed to be the same. Other within-block site variation must be minimal (no residual nutrient gradient from past fertilizer or fallow treatments).

14.2.5.3 Latin Square.—When site variation exists in two directions, the latin square design is used. Its advantages are: control of experimental error in two directions and the ability to omit columns or rows from analysis because of excessive plot mortality or damage. The major disadvantage or restriction is that the treatment number must be equal to the number of rows and columns in the design. This usually restricts treatments to 10 or less.

For example, figure 14-5 shows the herbicide t adapted to a site where moisture and fertility va tion exist. Each row and column has all four tr ments (three herbicides plus hand-weeded contr All tending operations are assumed to be the same each plot.

14.2.5.4 Split Plot.—This design is used when s treatments are best applied to large plots and ot to small plots. In practice, this means establish large plots first, then splitting them into small p to which minor treatments are assigned randoml

Figure 14-6 shows a split-plot design to test effects of two potting mixes and three seeding pr dures on germinating pine seed in contain Medium 1 (M1) is a 1:1 mixture of peat and ver culite; medium 2 (M2) is a 1:1 mixture of local comp and vermiculite. Sowing operations are direct (ha seeded (S1), fully automated by vacuum plate (and semi-automated box seeder (S3); two seeds sown per cavity.

Because of variability in seeding operations, replications are used. Traits assessed are: time each seeding (small plot) treatment to obtain 90 cent germination, total number of seeds germina in 3 weeks, percentage of full cavities (i.e., at least seedling per cavity), and mean height of germina after 3 weeks for each seeding treatment on e growth medium. Watering, damping-off control, sh ing, etc., are assumed to be equal for all containe

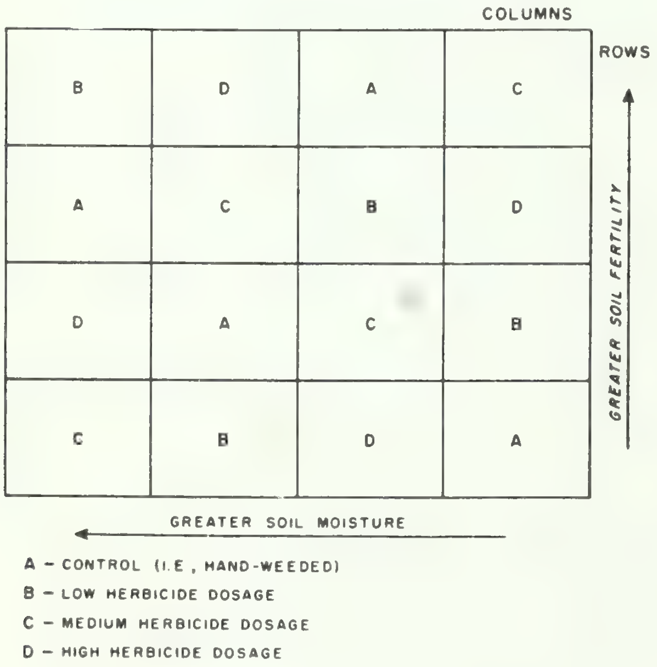


Figure 14-5.—*Latin square design for nursery experiment testing of three concentrations of a postemergent herbicide and hand-weeding. Bare-root pine seedling beds have moisture and fertility gradients*

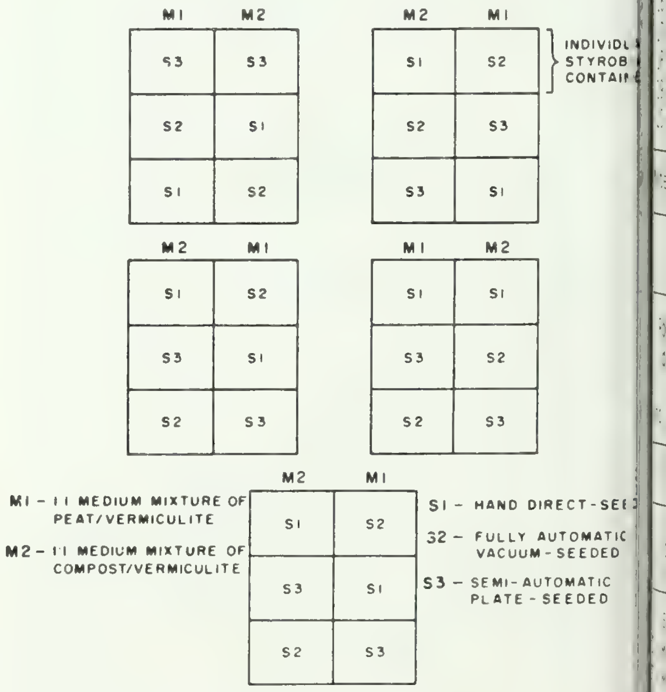

M1
M2
S3
S3
S2
S1
S1
S2
M2
M1
S1
S2
S2
S3
S3
S1
INDIVIDU
STYROB
CONTAI
M2
M1
S1
S2
S3
S1
S2
S3
M1
M2
S1
S1
S3
S2
S2
S3
M2
M1
S1
S2
S3
S1
S2
S3
M1 – 1:1 MEDIUM MIXTURE OF PEAT/VERMICULITE
M2 – 1:1 MEDIUM MIXTURE OF COMPOST/VERMICULITE
S1 – HAND DIRECT-SEE
32 – FULLY AUTOMATIC VACUUM-SEEDED
S3 – SEMI-AUTOMATIC PLATE-SEEDED

Figure 14-6.—*Split-plot design for nursery experiment testi effects of two potting mixes and three seeding o tions on germination and growth of pine seedlin the same-size Styroblock container.*

.3 Data Recording and Record Keeping

Accurate record keeping is essential for evaluating periments. Insufficient data or improperly recorded ta will prevent experimental questions from being swered adequately. Thus, experiment work plans ould include data-sheet examples of the nursery aits assessed (fig. 14-7), instructions on how and when assessments will be made, and guides on summarizing raw field data. Also, each study should have its own experimental design, clearly indicating blocks, replications, and position sequence for trees located in seedbeds.

Individual items may seem trite, but many experiments have been lost because sowing, tending, or measurement dates were not recorded or were

udy name/number	Block No.	Rep. No.
sessment date		

ee o.	Root collar diameter	Height	Tree No.	Root collar diameter	Height	Tree No.	Root collar diameter	Height
1			21			41		
2			22			42		
3			23			43		
4			24			44		
5			25			45		
6			26			46		
7			27			47		
8			28			48		
9			29			49		
0			30			50		
1			31			51		
2			32			52		
3			33			53		
4			34			54		
5			35			55		
6			36			56		
7			37			57		
8			38			58		
9			39			59		
0			40			60		
tes						Total No. Living		

- - - - - Means - - - - -

Root Collar diameter (mm)	Seedling Height (cm)	Root Collar diameter (mm)	Seedling Height (cm)	Root Collar diameter (mm)	Seedling Height (cm)
s. 1 to 20		Nos. 21 to 40		Nos. 41 to 60	

Summary	Age	N $\overline{D}$ $\overline{H}$	% Survival	

= Seedlings surviving at assessment.
= Mean root collar diameter (i.e., arithmetic mean of all surviving seedlings).
= Mean height (i.e., arithmetic mean of all surviving seedlings).
Survival = $\frac{\text{No. of seedlings surviving at assessment}}{\text{No. of seeded cavities in Styroblock}}$

gure 14-7.—*Example of a field data sheet for nursery research.*

recorded illegibly. Below is a list of procedures that researchers should follow when recording data.

14.3.1 Data Recording Do's and Don'ts.—No matter what format is used, *ALL DATA SHEETS SHOULD CONTAIN:*

1. Species or provenance planted and trait assessed.
2. Date of assessment—the month and day should be *written out* instead of using a numbering system that is not uniform throughout the world (e.g., November 4, 1982 instead of 11/4/82, which is also written as 4/11/82). Recording the exact date is critical for calculating seedling and tree growth rates in tropical regions where a dormant season is absent.
3. Names of person(s) who made the assessment and the traits they were responsible for (e.g., John Doe: seedling heights, Jane Doe: data recorder).
4. Notations on whether data are in metric or English units.
5. Complete identification codes for all treatments, including block and plot numbers for replicated experiments.
6. A separate column for unusual things observed in any plot or at the research site (e.g., insect attack, wind damage, or persistent drip damage from irrigation lines).
7. Numbers that are clearly and distinctly written—handwriting differs from one person to another, but if numbers are not recorded *clearly*, summarization by someone other than the recorder may be impossible.
8. Results of data that are summarized and analyzed *as soon as possible* after they were obtained—waiting months or years is not recommended because data become "cold" and inconsistencies are not caught in time.

Finally, before leaving the nursery, check that appropriate items have been completed on all data sheets and that assessment dates appear *on each page*. Catching errors and correcting them *before* returning to a distant office can save a 1-day trip back to the nursery site; simple omissions or inconsistencies can be spotted and corrected if accuracy is constantly checked.

14.3.2 Basic Statistics and Data Summarization.—Simple statistics used to summarize data from nursery experiments are the mean, standard deviation, variance, and coefficient of variation. A definition for each and an example of its calculation is shown in table 14-1.

Summarization of raw data, especially when done with a computer, is simple if the data are coded correctly on data sheets. One example is shown in figure 14-7. Formats will vary, depending on the study sign and traits assessed. Each sheet should be de oped well ahead of any measurement to ensure ease of use and versatility.

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CHAPTER 15

15. MECHANIZED CONTAINER PRODUCTION

5.1 Criteria for Selecting Containers

To select a suitable container, nursery managers ust answer several questions. What is the minimum ntainer volume needed for high seedling outplant- g survival? Which containers provide this volume? hat are delivery costs for the containers having ese volumes? And, what are anticipated overhead ages, administration, and facility depreciation) and rect (temporary labor, fuel, fertilizer, and pesticide) sts.

Of the many kinds of containers having the same fective root volume, some are reuseable; those not useable represent overhead or direct costs. Also, ight charges and import duties in overseas counies can be high for "bulky" containers. Factors afcting container volume and the major kinds of coniners used are discussed below; other authors treat e same topics in greater detail (*1*, *5*, *14*, *22*). With is information, managers can select the "optimum" ntainer for their needs and decide whether it is best rchased locally or elsewhere.

15.1.1 Length.—Before 1970, lack of research data made it difficult to select optimum container length. Today, data show that optimum container volume is closely dependent upon length (*21*, *23*). In general, short containers, 13 to 15 cm long, are best for areas having long wet seasons. Long containers, 20 to 25 cm, are best for areas having irregular and long dry spells where seedling root systems must be placed deeper into the soil to avoid rapid desiccation.

15.1.2 Shape.—The most common cross-sectional shapes are round and square. Container configuration is important because of its relationship to total volume. For example, a box container 5 by 5 by 20 cm in size has a volume of 500 cm^3; a round container 5 cm in diameter and 20 cm long has a volume of 392 cm^3, 22 percent less volume. Nursery benches and planting boxes can hold equal numbers of each container because of their geometrical design (fig. 15-1). Some containers are tapered at the bottom, reducing effective volume for a given length (fig. 15-2). Hexagonal shapes are common in expandable paperpots.

15.1.3 Volume/Design Influences on Roots.

15.1.3.1 Ribs.—Container design influences root formation and root growth pattern. Four or more internal vertical ribs (fig. 15-3) direct roots downward and prevent root spiraling within containers. Round, rigid containers usually have ribs that make them superior to non-ribbed containers.

15.1.3.2 Holding Time.—Container volume influences the length of time that seedlings are held in the nursery once they reach outplanting size. For small volume containers, holding time decreases, and for large volume containers, holding time increases, allowing more flexibility to accommodate planting schedules. Keeping seedlings for long periods after roots have reached the container bottom creates unbalanced root/shoot ratios, J-roots and spiraled roots. After they have reached outplanting size, seedlings should not be held more than 45 days when using small volume containers (<300 cm^3) and not more than 75 days when using large containers (>550 cm^3).

15.1.3.3 Drainage/Root Egress Openings.—Openings at bottom and sides of containers keep pot medium adequately drained. Bottom holes allow root egress and prevent root spiraling at container bottoms (fig. 15-4). Openings must be large enough to allow free drainage and root egress when necessary, and yet small enough to prevent loss of pot medium in filling, handling, and stacking operations.

15.1.4 Container Construction Materials.—Helpful questions to ask when considering ideal container construction materials are: Will containers be reused? Will the container be planted with the seedling, requiring it to be biodegradable? Will seedlings be machine-planted or hand-planted? Must seedlings be carried to planting sites far from roads? Which con-

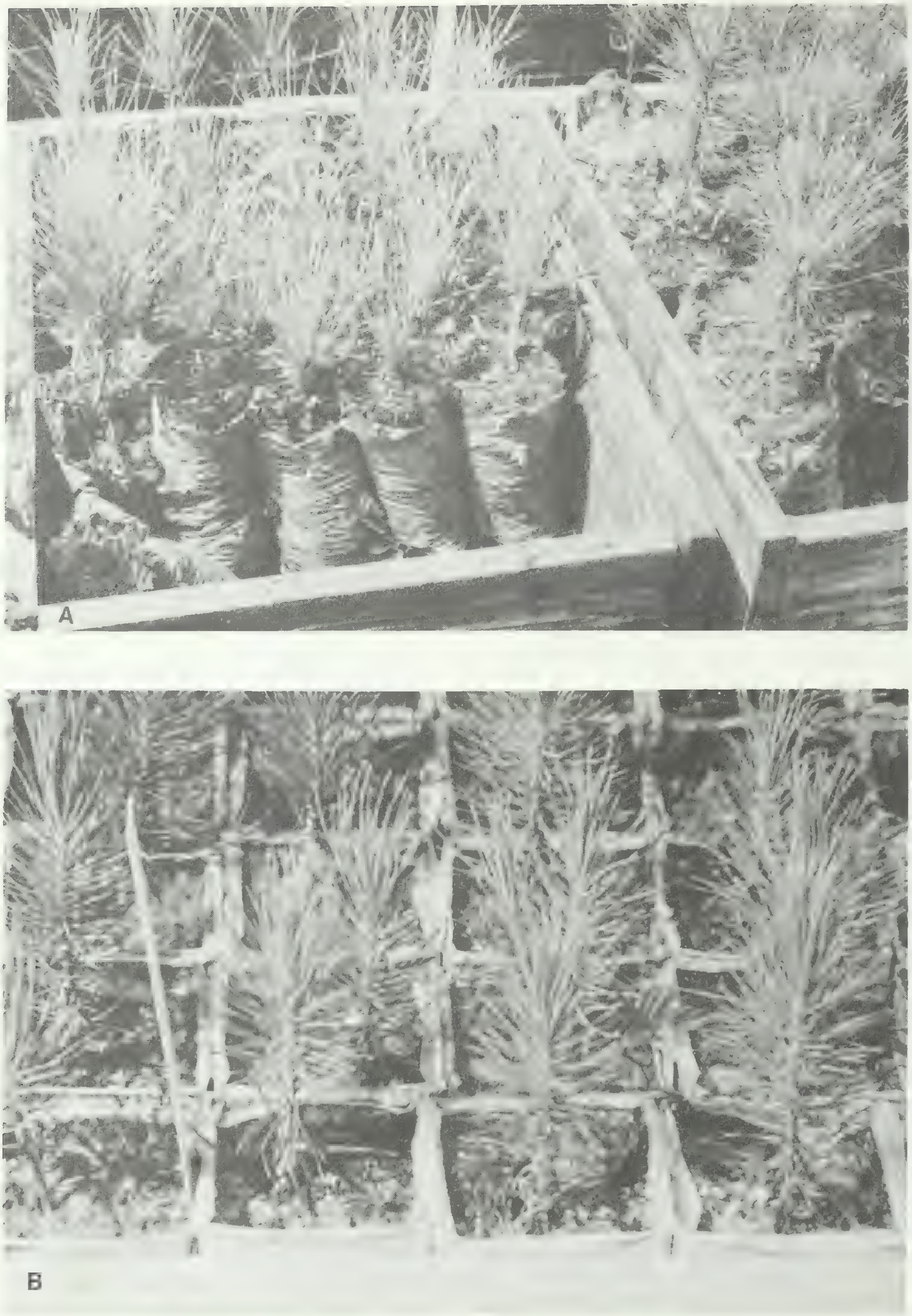

Figure 15-1.—*Shape/size pot considerations determine amount of medium needed, affect root growth and development, and dictate bench or ground space needed for lining-out. Volume of individual plastic bags (A) is ±22 percent less than that of Poly-pot containers (B) having same height and width; yet geometrical design of both types allows a given bench area or transport box to hold equal numbers of each container.*

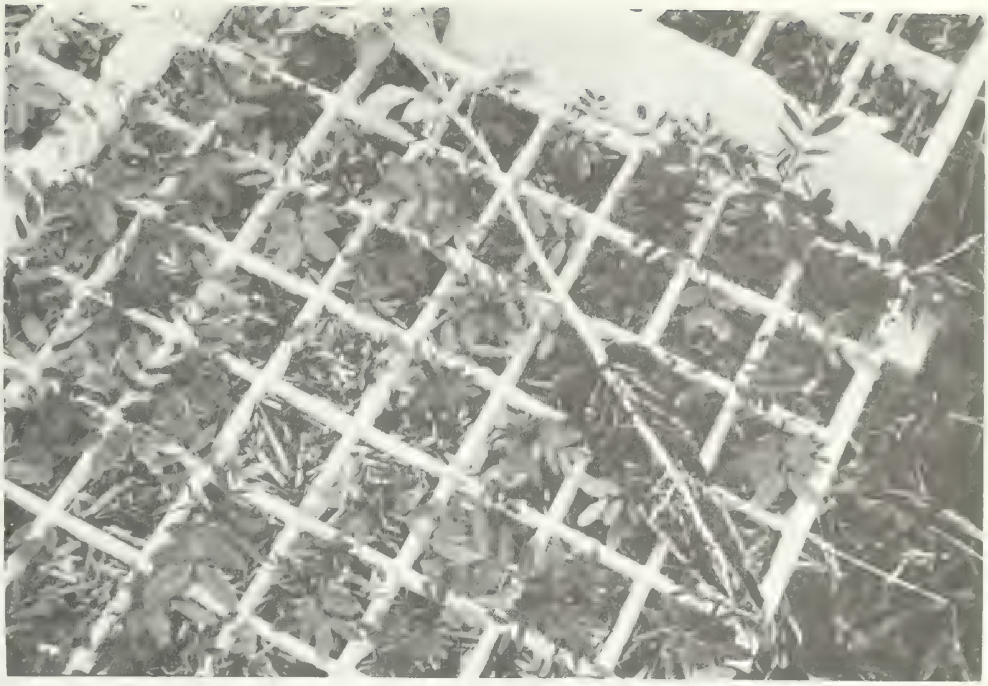

Figure 15-2.—*Cavities in the Todd Planter Flats have block cells that are tapered rather than having the same diameter at top and bottom. Taper severity influences calculation of potting medium needed, plug extraction at lifting, and root contact with soil when seedlings are outplanted.*

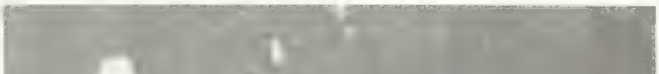

Figure 15-3.—*Leach Cone-tainer individual cell units of 10.2, 15.2, and 24.8 cm in length. All have internal ribs, running the length of each cell, which prevent root spiraling.*

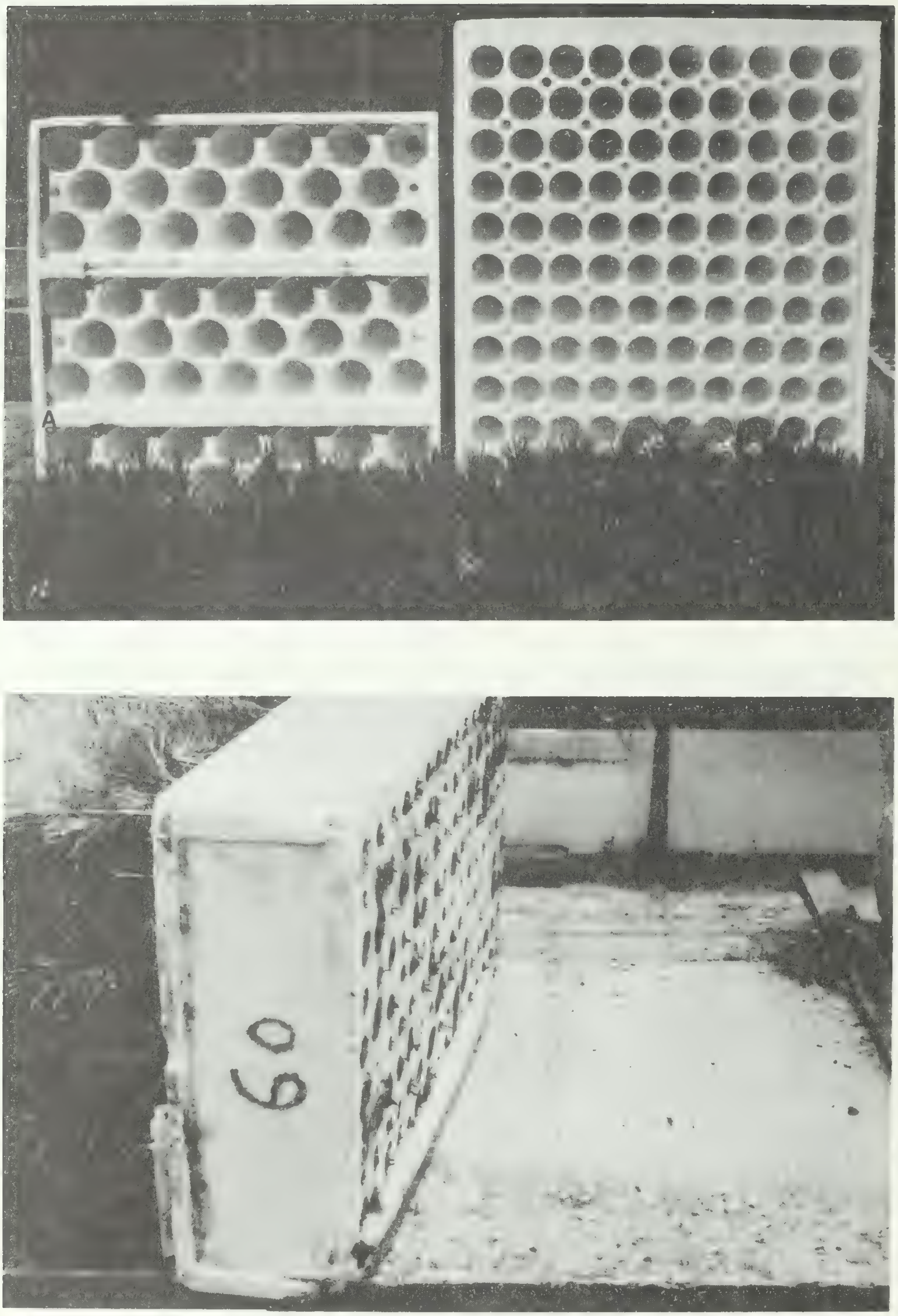

Figure 15-4.—*Top view (A) of Styroblock containers, showing large and small diameter cavities. Bottom view (B) shows root egress/drain vents and "runners" that keep the block off the ground to allow air-pruning of roots.*

ier type utilizes available nursery space most effi-
itly?
hese are important questions because container
e affects the entire production operation, including
degree of mechanization possible. For example,
cessing of plastic bags, including filling, sowing,
ering seeds, and transporting to the field (fig. 15-
cannot be as highly mechanized as processing of
roblocks (fig. 15-4).
everal lists of container product manufacturers
e been published (*1, 22, 25*). Unfortunately, lists
quickly outdated as new product lines are added
old ones are eliminated. Some manufacturers and
ir products are listed in Appendix 15.
5.1.5 Container Systems: Some Historical Per-
ctives.—Ornamental and vegetable nurseries
e used mechanized seedling production techniques
over 100 years (*5*). But only in the last 15 to 20
rs has enough interest developed to use highly
hanized sytems for forest seedling production.
nterest came from decisions to reforest marginal,
r, cutover lands in North America and Europe. On
h lands, survival rates of container-grown stock
greater than those of bare-root stock. Simulta-
usly, because affected countries have high labor
s, research began on mechanized techniques to
er production costs. Today, containerized stock
ches correct size for field planting in a much
rter time than does bare-root stock, and large-
e mechanized container systems for pine may be
ipetitive with bare-root operations (*11*).
n the tropics, abundant, cheap labor has restricted
elopment of mechanized container systems. In the
decade, however, two events caused a reevalua-
n of containerized systems for tropical areas where
il pot materials are available (*8, 14, 15*): high de-
nd for bagged pine seedlings (Surinam, Venezuela,
Brazil) and more demand for hardwood seedlings
nted in dry areas for agroforestry and fuelwood
jects (Haiti and Brazil). One of the most successful
rations was that of CONARE (Compañia Nacional
Reforestacion) and CVG (Corporacion Venezolana
yana) in Venezuela in which 100,000 ha were ma-
ne-planted with containerized pine (in plastic
s) between 1972 and 1979 (*3*).
iverse handmade container types commonly used
ude clay balls, split bamboo pots, plastic bags, clay
s, tarpaper pots, tin cans, and milk cartons. In gen-
l, nonrigid containers such as plastic bags
. 15-1) are filled individually by hand; rigid con-
ners such as tarpaper pots and tin cans are lined-
upright and filled by shoveling sieved, loose soil
r them. One disadvantage of the latter method is
t soil packs between containers and serves as a
dium for weed growth. Another problem with con-
ners is that, if roots egress and grow into soil under
m, the root system must be pruned or much of it is lost by stripping when pots are lifted. Some species are not suited for container production (*9*).

15.1.6 Major Container Systems of the 1970's and 1980's.—Container types and systems are discussed from different approaches. One approach lists three types: tubes, plugs, and blocks (*1*). Another lists two broad types and several divisions within each type (*22*), as follows:

A. Containers *planted with* seedlings:
  - A1—those filled with rooting medium: open mesh plastic tubes, and several paperpot systems (e.g., Conwed open mesh tubes, Walters' square bullets, and Alberta peat sausage).
  - A2—those not filled with rooting medium: molded blocks of peat, woodpulp, or plastic foam and fiber (e.g., Polyloam, Tree Start, and BR-8 Blocks).

Both A1 and A2 are respectively equivalent to the tubes and blocks of Barnett and McGilvray (*1*). But Walters' bullets are square, not round, and should not be confused with solid cells.

B. Containers *not planted with* seedlings:
  - B1—cells are individual units that can be unitized in trays or racks for easier handling; cells and racks are usually made of polyethylene (e.g., Leach Cone-tainer; fig. 15-5);
  - B2—*blocks* are units of separate cavities or cells that are *permanently attached* to each other;

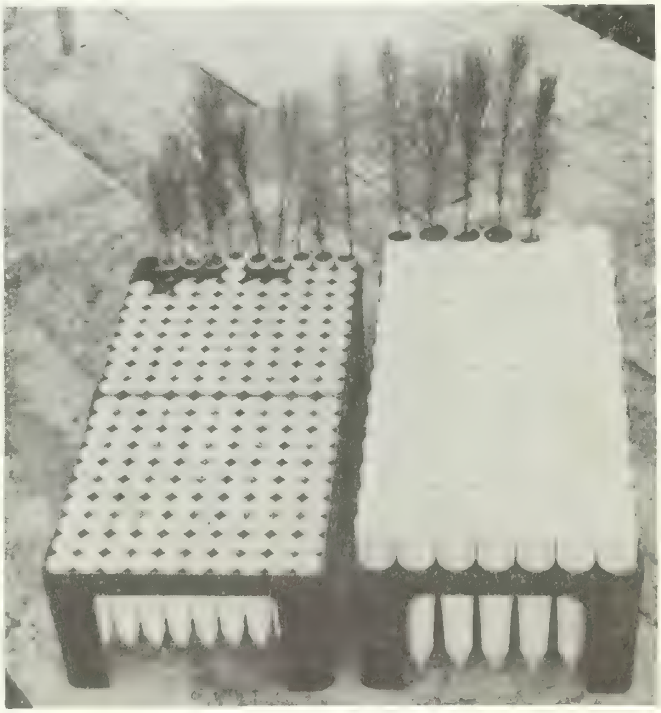

Figure 15-5.—*Polyethylene multipot tube containers that are unitized in raised trays or racks. Cells with cull seedlings or non-germinants are easily replaced with full cells.*

materials are high density polyethylene multipots and expanded bead polystyrene (e.g., Styroblock and Todd Planter Flats; figs. 15-2 and 15-4);

B3—books are units of cavities in rows formed from thin polystyrene sheet plastic; sheets have hinges and open like books (Spencer-Lemaire Rootrainer; fig. 15-6) or come in two pieces that snap together (Tubepak).

Cell and block/book designs correspond to Barnett and McGilvray's tubes and plugs respectively; "Speedlings" are really Todd Planter Flats, made by Speedling Inc. Book designs are also called "Rootrainers", because internal ribs direct root growth downwards.

Five container systems *particularly adaptable* to tropical areas are discussed in Appendix 15: Rootrainers, rigid polyethylene tubes, paperpots, Styroblocks, and Poly-pots. Some types are highly desirable because they are reusable.

15.2 Selecting Growing Medium

15.2.1 Ideal Medium Properties.—A suitable growth medium provides anchorage, nutrients, and moisture for growing seedlings (Chap. 9). Mechanized container operations also require that a growth medium be light, be easily handled, maintain constant volume when wet or dry, be free of pests, be readily stored for long periods without change physical and chemical properties, and be eas blended into reproducible materials. Sand and soil excluded because of their weight limitations. Pro ties of several "soil less" products having these spe qualities are briefly discussed below; more deta descriptions are given by others (*5*, *22*, *23*).

15.2.1.1 Peat.—Sphagnum peat is the basic com nent of pot medium used in growing containeri seedlings for forestry, horticultural, and agricultu purposes (*5*). It is also used for root cuttings (*18*) air-layering vegetative propagation techniques Managers are cautioned that "peat moss" is a catc for many separate components, including natu sedge peat, peat humus types, and many comn cially available mixes. Of these, sphagnum peat the best physical and chemical properties.

Sphagnum moss, on the other hand, consists of decomposed materials and is not suitable for tainerized growth medium. All peats are min poor, requiring fertilizer to maintain seedling grov acidity should be in the pH value range of 4.5 to Because the mineral and acidity status of peats variable, caution must be used when purchasing th so that the delivered peat actually has the pH va and nutrient levels advertised. For container mi up to 75-percent is used; 50-percent peat is usu adequate. Other components mixed with peat are miculite and perlite.

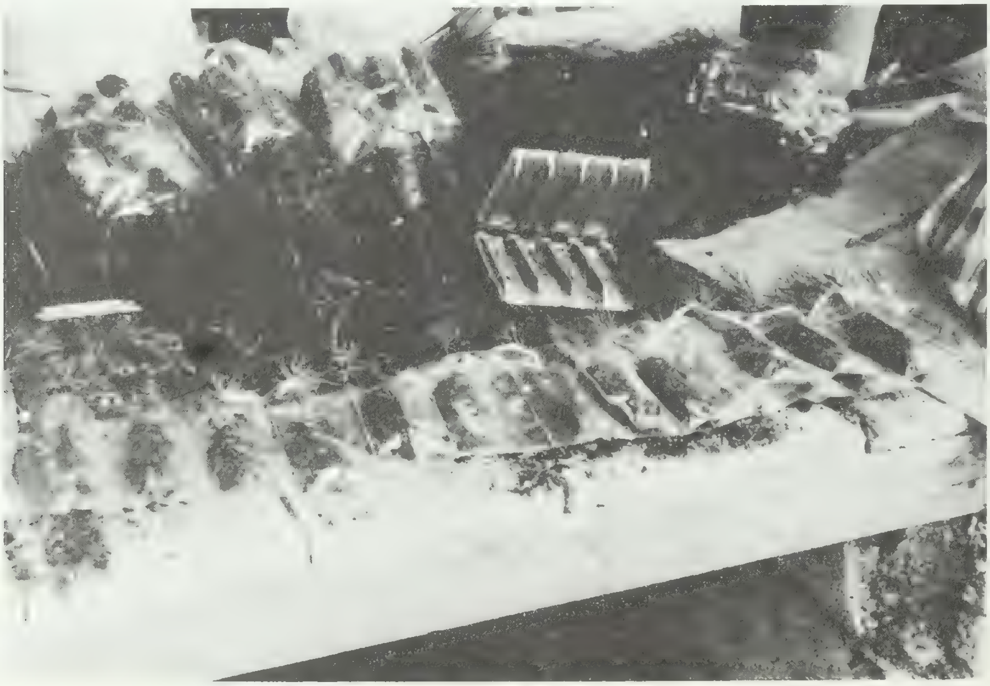

Figure 15-6.—*The Spencer-Lemaire Rootrainer (book planter) can be opened any time without disturbing the seedling to check for root development or to remove plugs for outplanting. When closed, internal ribs keep roots from spiraling. Containers are easily unitized in raised trays. If seedlings must be repacked before transporting and outplanting, this container is one of the easiest to use.*

Cost is the biggest drawback to using peat, particurly when it is shipped overseas. Yet, when seedlings ust be carried to remote planting sites, when no itable local substitute for peat exists, and when nds are available, the advantages of peat exceed st disadvantages. Peat moss costs are crucial when eciding ideal container volumes for species to be anted (i.e., the greater the volume filled, the more at used and subsequent higher costs).

15.2.1.2 Vermiculite.—Vermiculite is a bulking ent in pot mixes that keeps the growing medium om settling and compacting and maintains good aerion and drainage. It is a light, expandable, plateke 2:1 silicate mineral. After mining, vermiculite is n through high temperature (1,000°C) furnaces at force bound water out and plate layers apart. his process forms sterile, porous, sponge-like kernels at moisten and dry readily. Kernels are graded into rious sizes, from horticultural grade No. 1 (5 to 8 m) to No. 4 (0.75 to 1 mm). Products termed “attic l” and “poultry/kitty” litter are cheaper versions of ade No. 1; “block-fill”, however, is water-repellent eated and should not be used. Coarse sizes are best r large containers and finer sizes for seed germinaon trays and small volume containers.

Other advantages of vermiculite are:

neutral reaction and high buffer capacity;
high water retention capacity unless compacted queezed) when moist;
igh cation exchange capacity; and
enough natural Mg and K to supply most plants.

15.2.1.3 Perlite.—Perlite is another light, usually anular bulking agent made by heating crushed va. The resulting sponge-like, sterile granules hold to 4 times their weight in water and have a pH value 6.0 to 8.0; particle sizes are 1 to 3 mm. Unlike rmiculite, perlite lacks buffering capacity, cation change, and mineral nutrients. Its usefulness is to crease aeration and moisture retention in pot ixes.

15.2.1.4 Sugarcane Waste.—Another lightweight aterial with potential for pot mixes is the filteress cake that remains after refining sugarcane. The aterial is abundant and relatively cheap in many opical areas. Some of its physical and chemical propties have been studied (table 15-1).

The following data and recommendations are taken om a report on filter-press cake by Samuels and andrau (*19*): It easily absorbs moisture when dry d its volume-weight ratio is low. Of the major plant trients, filter-press cake is highest in P and P_2O_5; N ntent is somewhat lower. The K content is low and erages 0.44 percent as K_2, with a range of 0.02 to 77 percent; the higher figure is extremely rare.

Calcium content is high, averaging about 3 percent CaO. Magnesium and minor elements such as Mn, , and B are present in sufficient amounts for use by plants. Except for the lower K content, the fertilizer value of filter-press cake may be as great as that of animal manures. Its main advantages are cheapness, slow release of nutrients, minor-element content, high bulk and high water holding capacity, high exchange capacity, and mulching properties.

Table 15-1.—*Chemical composition of filter-press cake residue of sugarcane*[1]

Constituent	Composition on a dry weight basis	
	Average	Range of values
	Percent	
Nitrogen (N)	2.19	1.07–3.13
Phosphorus (P_2O_5)	2.77	1.34–6.30
Potassium (K_2O)	.44	.02–1.77
Calcium (CaO)	3.05	.98–6.24
Magnesium (MgO)	.49	.42–.58
Manganese (MnO_2)	.17	.10–.24
Iron (Fe_2O_3)	1.05	.26–4.71
Boron (B_2O_3)	.01	.00–.02
Organic matter	39.50	....
Loss on ignition	42.20	....
Sucrose	3.00	2.00–4.00
Moisture (fresh)	61.00	59–69
Moisture (stored)	15.00	9–47
Volume weight[2]	.375	.372–.378

[1] Source: (*19*).

[2] Calculated on a dry-weighted basis.

Filter-press cake is an attractive lightweight substitute for peat. A major disadvantage is its high pH value, which ranges from 8 to 10. Obviously, this value must be lowered to about 5.5 if this material is to be used for growing pine seedlings. This can be done by composting filter-press cake with animal manures, then treating it with an acidic fertilizer that lowers pH value and supplies N (table 13-9).

15.2.1.5 Rice Hulls.—An excellent substitute for vermiculite is rice hulls. They are lightweight, have high bulk, hold moisture well, and are easily obtained in rice-producing countries. Depending on processing standards, grinding may be needed to increase flowability of rice hulls in mixing and filling operations. Rice hulls can be used in composts and as a germination medium in seed trays.

15.2.1.6 Compost.—Compost is a useful potting medium ingredient if the composting process is closely controlled. Potentially desirable traits of compost are:

- low weight, depending on major components used;
- low shrinkage;
- good moisture retention;
- inexpensive once local sources of raw materials are identified;
- high fertility if properly prepared;
- easily shredded and screened to uniform size;
- mixes well with sand, perlite, and vermiculite; and

- does not immobilize nitrogen or other nutrients.

Major criteria for judging compost are how well it provides good aeration, maintains acidity, and reduces unit seedling weight in containers. Fertilizer amendments provide elements that are missing or in short supply in the compost. Potential problems in making compost are:

- obtaining a steady source of homogeneous, raw compost materials (rice hulls, horse manure, cow manure, etc.);
- making compost in time so that material is ready for the beginning of production runs;
- obtaining an end product that is free of pests and disease organisms; and
- avoiding C:N ratios that are too high (≥30:1) in finished compost material.

Appendix 13 outlines procedures to produce compost of desirable physical, biological, and chemical composition (*16*).

15.2.1.7 Wood Products.—Sawdust, wood shavings, and ground bark can be used in place of sphagum peat in pot mixtures. Sawdust and bark are not used exclusively but are mixed with other materials. Aged or composted wood products are best because fresh materials have high C:N ratios, ≥150:1 (*22*), that immobilize N and make young seedlings chlorotic. Some fresh barks have chemicals that are toxic to plants.

Advantages of wood products in pot mixes include lightness and ease of handling when ground, moderate cation exchange, and small but significant amounts of all major and minor elements. When cost is not a limiting factor, sphagum peat is still preferred because it has higher cation exchange, better C:N balance, and fewer problems with harmful organisms and toxic substances.

15.2.2 Optimum Growth Medium

15.2.2.1 Porosity and Aeration Considerations.—The "optimum" growing medium for a given situation depends on several factors, including requirements of the species grown, container volume, and available pot mix (*12*). Seedlings do better in moist rather than dry or wet media. Shallow containers with fine textured materials have better moisture retention but poorer aeration than deep containers with coarse textured materials because of less medium porosity. Porosity determines the space available for water, air, and root growth. Large pores aid aeration, whereas small to fine pores aid water retention; thus, both are important.

Spomer (*21*) developed a simple procedure for determining container porosity, aeration porosity, and water-retention porosity (table 15-2). Generally, aeration porosity values <10 percent are considered low; values >25 percent are considered high.

15.2.2.2 Examples of Mix Proportions.—A 1:1 mix of shredded sphagnum peat and vermiculite minimizes weight and facilitates container handling most mechanized operations. Other mixtures used a 3:2 and 3:1 ratios of the same components (*22*). Som nurseries successfully use peat without vermiculite perlite. Examples of homemade medium are 2:1 mixtures of bagasse (sugar-pressed cane fibers), ri hulls, and alluvial soil in Haiti (*20*); 2:1 alluvial soi filter-press cake mixtures at the Monterrey nurser in Puerto Rico; 1:4 and 2:3 ratios of topsoil and san and 2:3 ratios of rotted cow manure and builders san (*13*); and a 4:3 mixture of sand with well sieved compost (*7*). Most tropical countries do not use "soil less medium.

The proportions of medium component affe seedling growth by changing porosity and drainag Adding more vermiculite or perlite to peat increase aeration and drainage (*4*). But too much vermiculit allows pot mix to fall through drainage holes, whic can cause seedling plugs to fall apart when they ar removed from containers. Areas of constant humidit

Table 15-2.—*Procedures for determining total porosity, aera porosity, and water retention porosity of conta media*[1]

Materials	Procedures
Container with drain hole at bottom, plug for drain hole in container, and graduated cylinder or other device for measuring water volume.	1. Plug drain hole and fill container with water; measure volume of water in container (= *container volume*). 2. Empty container and fill with soi mix; slowly and thoroughly sat rate mix by adding water at on edge of container and keeping track of water added (= *total p volume*). 3. Unplug drain and catch water th runs out; measure volume of water drained (= *aeration pore volume*). 4. Porosity is obtained by dividing pore volume (step 2) by contain volume (step 1). 5. Aeration porosity is obtained by c viding aeration pore volume (step 3) by container volume (step 1). 6. Water retention porosity is obtain by subtracting aeration porosity (step 5) from porosity (step 4).
In Summary:	
Porosity (%)	$= \frac{\text{container mix pore volume}}{\text{container volume}} \times 1$
Aeration porosity (%)	$= \frac{\text{aeration pore volume}}{\text{container volume}} \times 100.$
Water-retention porosity (%)	= porosity − aeration porosity.

[1]Source: (*21*).

d high rainfall require better drained (coarser) xes, whereas dry areas need finer medium with ore moisture retention.

15.2.2.3 Synthetic Mixes.—Commercial pot mixes er advantages to some nursery managers. Examles are Jiffy-mix, Pro-mix, and Redi Earth. All come e-mixed to be placed directly into containers. Most e sterile and have pre-added nutrients. Disadvanges are their high cost, no control over components the mix, unneeded or nonbeneficial nutrients, and s than ideal aeration and drainage. Buying coniners prefilled with synthetic mix may be cost effece when seedlings are needed in the shortest time ssible, as in erosion control and landslide stabilizan. Appendix 15 lists commercial suppliers of pot xes and their addresses.

.3 Basic Equipment

The right equipment is essential for mechanized ntainer systems. Design and parts may vary by untry, but the functions of basic pieces are the me. Equipment used at the ITF nursery in the late 70's to produce pine seedlings in Styroblocks (*26*) is scussed below. Gravity feed systems compliment achines whenever possible in all operations (see Apndix 15).

15.3.1 Compost Shredders.—Shredders (fig. 15-7) ocess agricultural byproducts such as filter-press ke, coffee chaff, rice hulls, coconut hulls, straw, etc., fore they are composted. Shredding forms small rticles, increasing surface area for more rapid demposition. After composting, a final shredding eaks up remaining clumps; improves filling and setng of medium into small cavities; and allows better xing with perlite, vermiculite, and other medium mponents.

Shredders are integrated into production operans in two ways. In one method, equipment is set on evel area. Shredded material falls onto a mechani l conveyor, is transported to a large mixer, and is iformly mixed with other components before being nsported to a filling hopper.

In the second method, shredders are in the upper vel of a split-level building; gravity then feeds redded material into a mixing hopper on the first vel (Appendix 15), thus eliminating the need for a nveyor belt.

Shredders come in various sizes. Those with the pacity for grinding about 7.5 m^3 of material per ur are adequate for nurseries producing ≤1 million edlings per year. Electric models are less noisy than soline powered shredders. Either types must be ghly mobile and relatively trouble-free in operan. Raw shredded material, ranging from 0.2 to 0.5 long, should be screened so that the final product to 6 mm) is homgeneous.

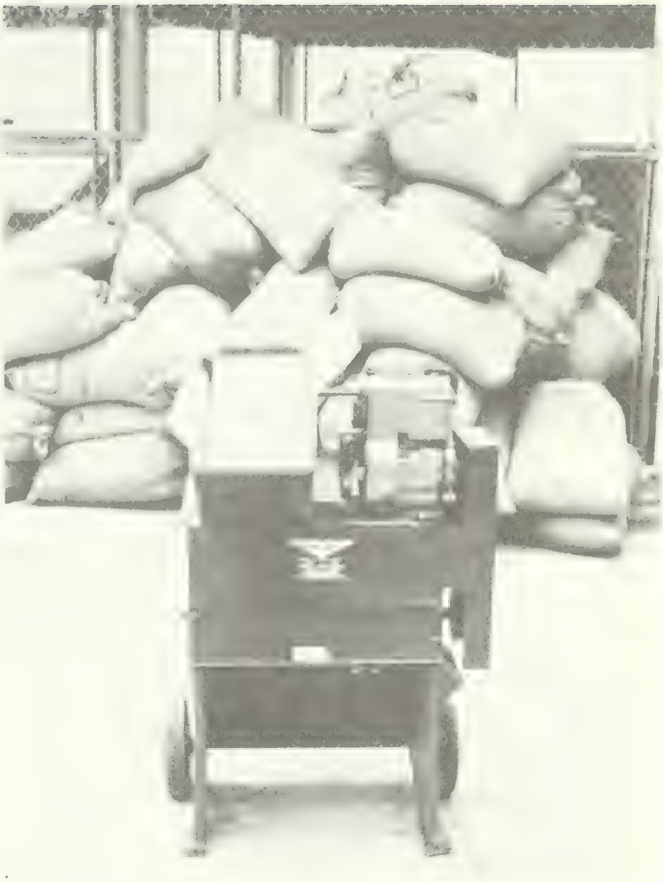

Figure 15-7.—*A small, very mobile, gas-powered compost shredder capable of processing 7 m^3 per hour of rice hulls, sugarcane waste, straw, and other materials.*

15.3.2 Soil and Compost Sievers.—Unsieved pot medium can cause poor aeration and poor drainage. Final medium should have a consistency that minimizes silting and that has sufficient large-size particles. Up to 50 percent of the pot medium should fall through 1.4- to 2.4-mm sieve openings. Very fine sand, perlite, vermiculite, and expanded polystyrene beads are excellent lightweight materials that increase bulk and improve drainage, porosity, and aeration.

Mechanical sievers can sieve 3 to 5 m^3 of material per hour. Hand sieving is done if machines are not available. Ideally, a mechanical siever is placed between the shedder or soil mixer and the mixing tank.

15.3.3 Medium Mixer.—Concrete mixers or some similar machine (fig. 15-8) should have a 3 to 10 m^3 capacity. Medium ingredients enter by gravity feed or by conveyor belt. The mix is wetted to improve flowability; the material is moist to the touch, but excess water cannot be squeezed out with the fingers (Sec. 15.4.2). After mixing, the final medium is transported to a filling hopper.

15.3.4 Potting Machine.—Vibrating plate-type machines are capable of filling a tray with containers

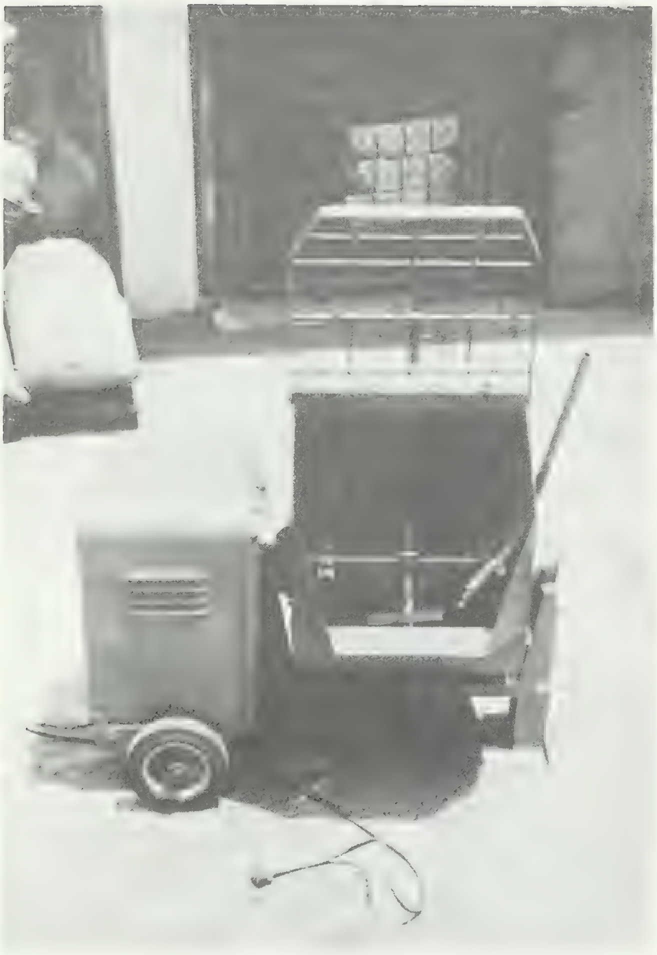

Figure 15-8.—*A small electric mixer capable of processing 3 to 10 m^3 of potting material per hour.*

in 20 seconds. A single machine can fill 80,000 to 300,000 cavities per each manday of work, depending on cavity volume, kind of pot medium used, and container types (e.g., rigid types being easier to fill than flexible or assembled types). For less mechanized operations, one worker can take medium from the filling hopper and fill containers by hand or by gravity feed (fig. 15-9). After flats are filled, they are sent by conveyor belt to the semi-automatic seeder.

15.3.5 Semi-Automatic Seeder.—Before seeding, compactors push pot media down about 1 cm, creating space for seeds (fig. 15-10). Vacuum controlled seeders fit exactly over cavities of multiple cavity flats (fig. 15-11). After aligning the plate with seeds over the containers, vacuum is cut and the seeds fall into the cavities. One operator can easily seed 100,000 cavities in an 8-hour day.

A hand-operated seeder can be made of plexiglass to fit any cavity configuration. It has two sliding plates with matching holes, the bottom plate having a slightly larger diameter hole than the top plate. When the holes are unaligned, each hole is filled with seeds. Sliding the top sideways allows the seeds to fall
straight through the bottom plate into underl
cavities. Commercially made seeders can be
chased to desired specifications.

15.3.6 Final Filler.—Machine or hand sprea
place a small amount of vermiculite or other
cover over seeded cavities as they pass under a hop
(fig. 15-12). Excess covering of seeds will lower ger
nation. After applying the filler, mist watering ke
it from blowing away. A final filler is not neede
tightly enclosed, high-humidity germination hou

15.3.7 Forklift and Wagon.—Seeded flats
stacked manually on pallets, loaded by forklift
wagons, driven to seedbeds, and lined-out (fig. 15-
Lining-out is a potential bottleneck because work
need considerable space for maneuvering a fork
and accommodating the flats. Lift operators mus
skilled to avoid spilling loaded trays and damag
flats. Pallets can serve as permanent bench tops.

15.4 Other Operational Techniques

Other operations are essential to produce healt
vigorous seedlings. We review these operations bel
giving alternatives whenever possible and their
tential problems.

15.4.1 Medium and Facility Sterilization.—
mixes with peat, vermiculite, and perlite as ma
components do not ordinarily require sterilizat
Mixes with ground bark, sawdust, compost, and
should be sterilized. In research trials, all mix tre
ments, including the control, are sterilized (exc
trials on the effects of sterilization treatments).

Steam heat sterilization is preferred for "soil le
mixes. Chemical fumigants can bond to vermicu
and finely ground peat and compost, being toxi
plant roots even after treated material is aerated
fumigants are used, mixes should be moist, but
wet; fumes dissipate in 2 days to 2 weeks, depend
on the product used. Steam heating at 82°C for
minutes effectively kills most pathogenic pests a
weed seeds. Since steam heating is used extensiv
for horticultural and vegetable crops, a wide range
sterilization equipment is available. Dry-heat ste
ization can alter soil chemical properties (*17*).

Medium mixing and filling areas, plus the equi
ment involved, should be kept clean and free of we
seeds and other contaminants. Disinfecting alter
tives are washing with solutions of commercial blea
(50-percent sodium hypochlorite) diluted 10:1 w
water, boiling water, rubbing alcohol, and live ste
(*22*). Flats, tools, and nursery walls and floors sho
be disinfected before each production run.

15.4.2 Filling Container Cavities.—Slightly mo
medium flows better through the potting machine a
does not fall out of root egress holes as does
medium. Water is added to all components when th
are mixed. Peat and other finely ground materials

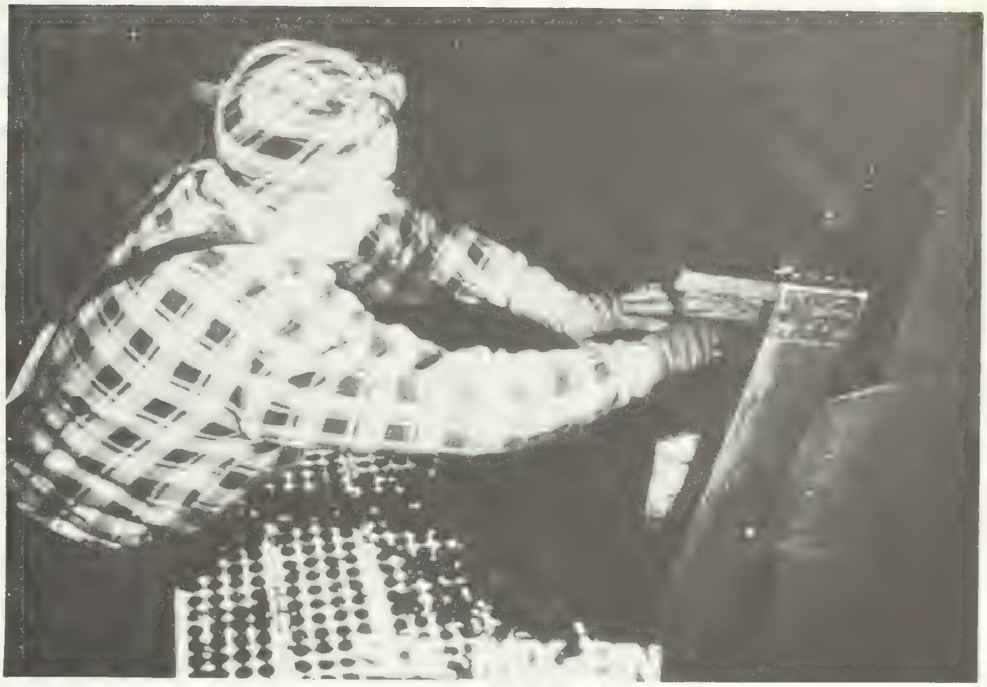

Figure 15-9.—*A semi-automatic potting operation in which a worker hand-fills containers passing underneath the medium hopper on a conveyor belt.*

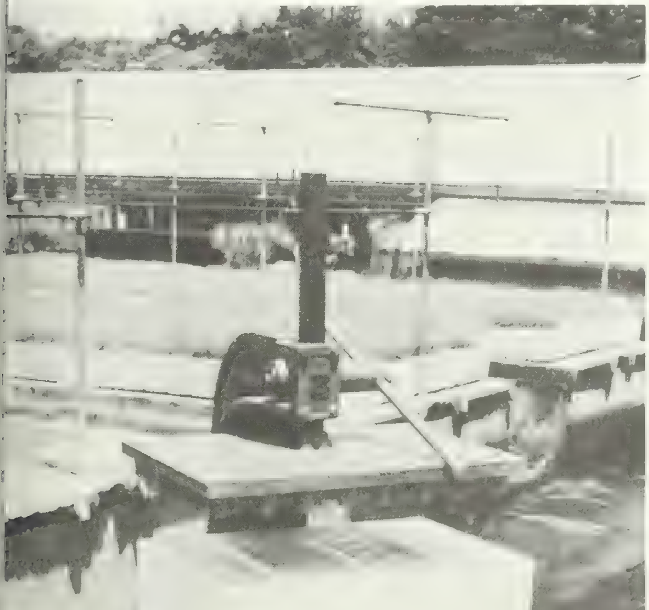

Figure 15-10.—*A hand operated mix compactor that presses down pot medium. Hand-operated plate seeders function the same way.*

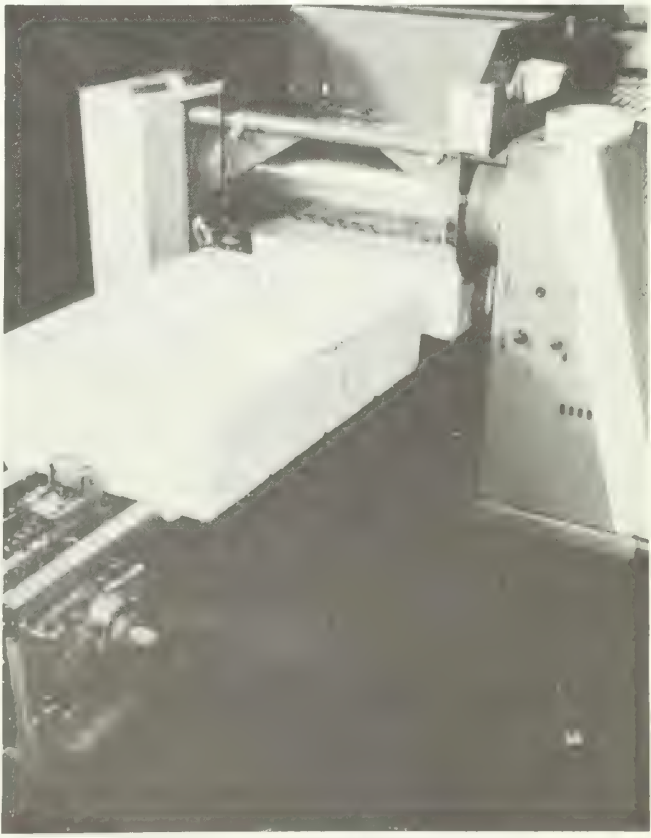

Figure 15-11.—*A vacuum controlled mechanical seeder that fills all container cavities simultaneously as Styroblocks pass underneath on conveyor belt.*

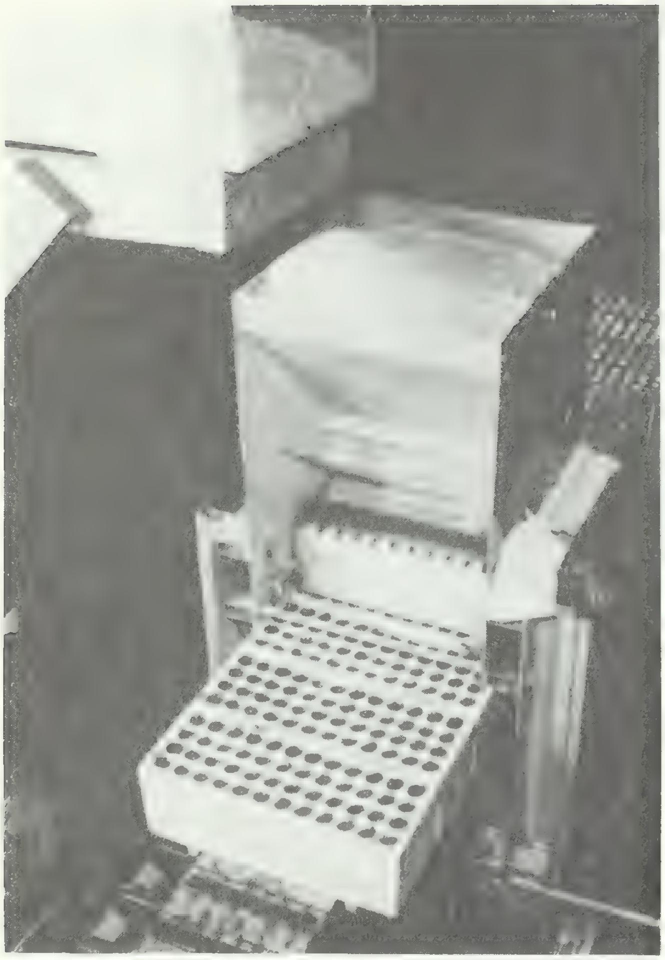

Figure 15-12.—*Mechanical final-fillers drop a thin layer of vermiculite or other grit over seeds in Styroblocks to conserve moisture around seeds and protect against birds.*

not wet well when dry because of their nonwettability (hydrophobicity) properties. Commercial wetting agents improve moisture uptake, but chemicals in them can lower the percentage of seed germination (*22*). Once pot mix is damp, it must be used before drying out.

Motion of the potting machine helps fill containers when pot mix is damp. Operators *must not* force extra medium into cavities with their fingers. A flat-handle brush smooths away any excess, which is eventually used.

15.4.3 Sowing.—Germination percentage of seed lots determines sowing rate. If germination is low, more seeds are sown per cavity, increasing the probability that each has at least one germinated seed. If germination percentage is high or seeds are scarce, then only one seed is sown per cavity.

If seeders pick up and drop only one seed per cavity, the entire operation is repeated 2 or 3 times. Automated seeders are faster than hand seeders but are subject to more mechanical problems. When automated seeders break down, hand sowing gets the job done (Sec. 9.1.5.2). After sowing, containers are sprayed with a fine mist to moisten seeds before going to the final filler.

15.4.4 Lining-Out and Germinating

15.4.4.1 Stacked Method.—Stacked containers in a germination house save outside bench space and reduce seed loss to birds and mice (fig. 15-14). The method is only suitable for species, including *P. caribaea*, that germinate uniformly in short periods and grow well in low light conditions. One drawback to the method is the need for placing wooden “stickers” between Styroblocks. They create space between block layers to prevent fast growing early germinants from bending over block tops. Seedlings straighten up if they have not been bent over too long, but mishandling blocks in lining-out will sever seedling tops that are bent over block edges.

Blocks stacked in criss-cross fashion cannot be watered. Thus, germination houses are used only for species having fast, uniform germination that is completed within 7 to 10 days in a high-humidity environment.

15.4.4.2 Lined-Out Method.—This method involves placing seeded containers directly on outside benches (fig. 15-13). Placing flats under about 30-percent saran shade for up to 21 days prevents loss from pests. Elevated shade is better than clear or dark plastic sheeting placed over containers. In the tropics, the latter practice can cause extremely high temperatures under the sheet that are lethal to germinating seedlings. Frequent and careful watering will keep medium and seedlings moist but not too wet; overwatering favors damping-off.

To reduce overtopping of border by interior seedlings, Styroblocks should be placed in long, narrow rows about 10 blocks wide. If peat or other sterilized pot medium is used, weed growth is minimal in exposed cavities. A wide walkway (76 cm) between rows can be narrowed to a small path (38 cm), which is adequate for inspecting seedling stock for pests and general growth performance. Narrow walkways leave more space for containers per unit of nursery area.

15.4.5 Thinning, Transplanting, and Grading.—Early germinants remain in the original container. From the 7th to 13th day after germination, small excess seedlings in each cavity are lifted and transplanted into empty Styroblocks. After the 14th day, small excess seedlings are removed and discarded. Small, less vigorous seedlings are not transplanted because they perform more poorly than do early germinants (*24*).

Long lateral roots on thinned seedlings should be carefully clipped rather than removed; this procedure avoids disrupting the growing medium around seedlings left in each cavity. Transplant holes should not be closed over J-roots (Sec. 10.1.1.2).

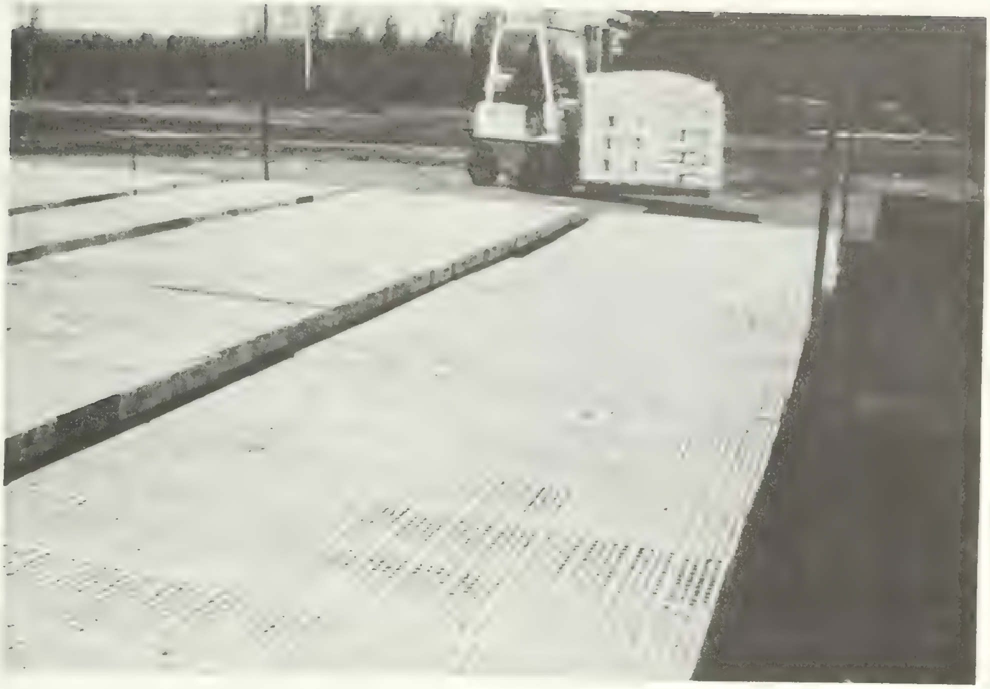

Figure 15-13.—*In large operations, forklift tractors are handy for lining-out seeded Styroblocks for germinating in the open air.*

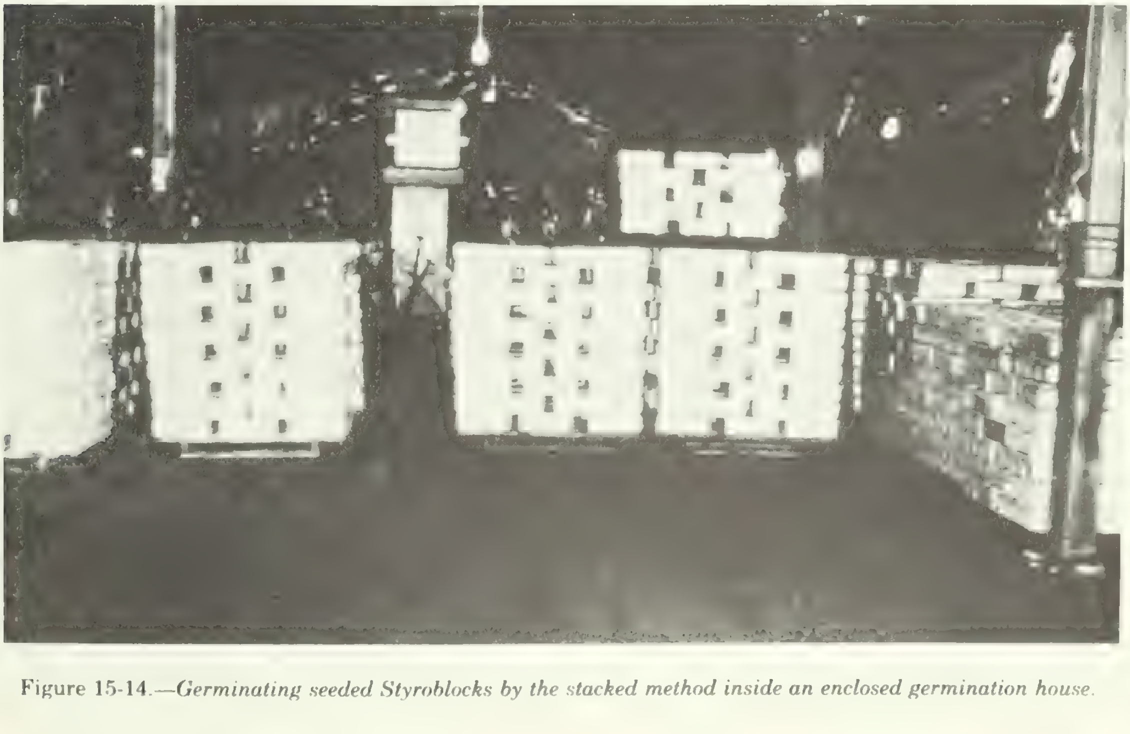

Figure 15-14.—*Germinating seeded Styroblocks by the stacked method inside an enclosed germination house.*

These thinning and transplanting techniques separate germinants into three classes: early, more vigorous germinants that are left in original containers and lined-out in one sector of the nursery; later, excess germinants that are transplanted into separate Styroblocks; and late germinants that are culled. Sometimes, late germinants are kept if germination is poor or if seeds are scarce. The result is seedlings graded according to date of germination.

15.4.6 Later Tending Care

15.4.6.1 Moisture and Fertilizers.—The moisture and fertilizer needs of seedlings are different for germination, juvenile, exponential, bud development, and stem lignification growth phases (*22*). Specific guides will depend on the containers used and species grown. Some general guides and suggestions are given in this section. For container operations, fixed irrigation systems are used more than mobile ones. Systems producing small and medium droplets (mist, semi-mist, and fine spray-nozzle types) are better than those producing large droplets. Smaller droplets do not damage young seedlings or wash out pot mix.

Persistent drip of fixed systems may wash out seedlings or medium from containers. Alternatives to prevent this are supplying water from beneath (*2*) or alongside benches (i.e., not from overhead), drawing water from the top of overhead pipes, draining out excess water after each use, and running a line down from the nozzle to the bench surface between containers (*22*). Large spray-nozzle and impulse-type systems are more adapted to irrigation of bare-root nursery beds.

Combining slow-release fertilizers with pot mix or top dressing fertilizers on container surfaces (*10*) is not usually done in mechanized container operations because:

- soluble fertilizer pellets or granules are readily leached from the pot mix;
- when seedling growth stages change, certain nutrients must be added or reduced; if they are already in the mix, controlled additions or reductions are impossible;
- pellet and granule dissolution are uncontrollable; thus, specific nutrients are not always provided when needed most; and
- slow dissolving fertilizers often tend to raise medium pH value and salt content; lowering both requires flushing with excess irrigation water.

For containerized systems, nutrients are usually applied through the irrigation system. Fertilizer formulation, concentration, and application frequency are easily controlled. The general scenario of watering and fertilizing for different seedling growth stages is:

1. *Germination stage*—frequent but controlled waterings to keep medium moist but not wet; no nutrients are added that provide "rich" materials for damping-off or c er pathogenic organisms.
2. *Juvenile stage*—less frequent irrigation at allows the growth medium surface tc ry between waterings; high P and K nd lower-level N fertilizers are added to r ximize early growth; a final rinse of fol ge with plain water is needed to avoid p sibility of salt burn and alga growth.
3. *Exponential growth*—reduce watering; lanced N-P-K fertilizers are ad d; seedling growth rates (too fast or too s w) are closely monitored to anticipate cha ge to next water and fertilizer regim or other corrective action such as ppruning.
4. *Bud development or stem hardening*—w n seedlings reach desirable height and re purposely drought stressed (harden); this process is done by heavy waterin to remove N and then subsequent dryin of seedlings almost to the wilting point; t y are rewatered to stop wilting and then nfrequently rewatered with low N and h P and K fertilizers to facilitate harden g.

Other nutrients are added according to the ne ls shown by periodic foliage testing (Chap. 13). Ur xpected micronutrient deficiencies are usually rrected by applying foliage sprays rather than s d materials.

15.4.6.2 Protection and Pest Control.—The gu es discussed in Chapters 12 and 16 can be followed. n general, reduced exposed area and use of unconta inated pot medium reduce weed growth more in a tainer than in bare-root nurseries. Consequen y, weeding is minimal and confined to borders f benches and is controlled by hand or by chemic s. Judicious use of asphalt, cement, turf, and gravel r roads and walkways will reduce weeding.

Having a cat or two around germination hou s, potting sheds, and outside benches is an effective c ntrol against mice, rats, and birds. Pathogen buildu s avoided by composting or burning thinned, cull, d other seedling materials. Otherwise, looking c stantly for problems and using approved pestici s should keep most pests in check.

15.4.6.3 Inoculation with Mycorrhizal Fungi.— r large potting operations, collected mineral soil d duff with inoculum is kept fresh for long periods y storing in burlap sacks lined with plastic or in b s lined and covered with plastic sheeting. When t components are mixed, inoculum is added 2 to 3 p cent by volume. Adding inoculum this way has ri s that are minimized by collecting inoculum fr n healthy plantations and by careful monitoring r damping-off, root rot, and other problems as inc lated seedlings develop.

15.4.6.4 Root/Shoot Growth Control.—Mechani l root pruning is not possible for containerized st . Root growth is controlled by the shape-volume-des n haracteristics of containers used (Sec. 15.1). Since oot volume is finite, estimating outplanting dates nust be accurate because long-term holding of eedlings is impossible. If seedling top growth has een excessive in relation to root growth, tops may be lipped back. This procedure stops top development, ncourages more root development, and produces beter shoot/root ratios (see Chap. 11).

Using wide rows minimizes border or edge effect round containers and reduces overtopping of interior y border seedlings. Effective windbreaks and proprly maintained irrigation systems reduce water and utrient drift from bench edges, giving edge and inteior seedlings the same moisture and fertilizer losages.

Experience at the ITF Nursery showed that bench olor and container placement affected seedling rowth. When concrete benches were new and highly eflective, seedling mortality was sometimes great ear bench edges when containers were set far to the nside (i.e., exposed to the reflective bench surface). pparently, localized heating or higher evapotranspiation was responsible (fig. 15-15). Alternative soluions are using less-reflective surfaces, such as wood r screens, over elevated pipes (fig. 2-2B); painting ew benches with less-reflective paint; and positionng containers so they extend over bench edges.

15.4.7 Lifting, Packing, and Transporting.—In he tropics, delivering containers directly to the field or outplanting is preferred. The lifting and repacking rocedure (fig. 15-16) is not recommended because it s time and labor consuming, can cause severe root lamage, and augments transplanting shock. Local

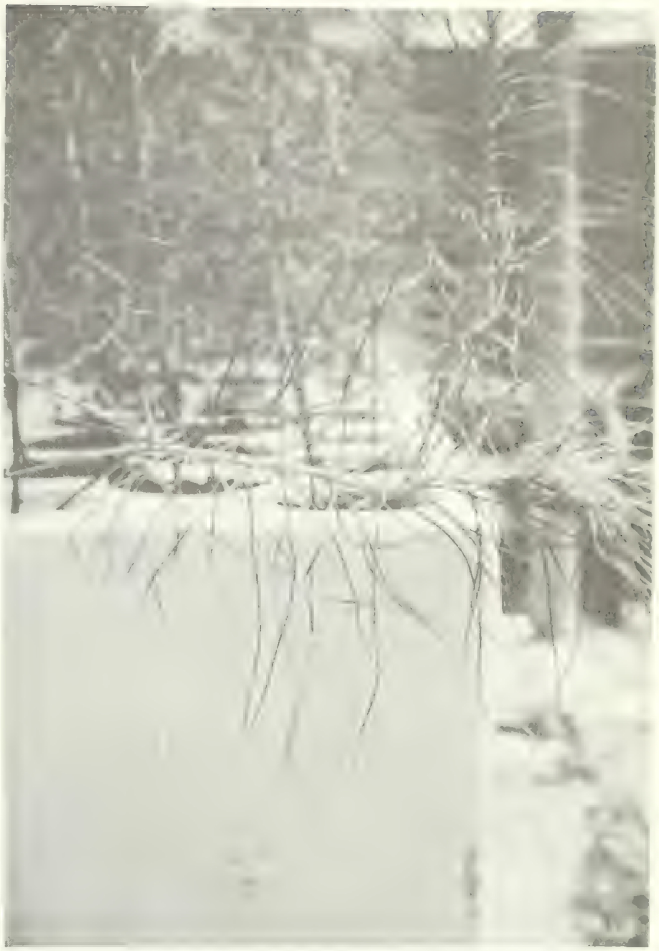
Figure 15-15.—*Mortality of pine seedlings at edges of Styroblocks may have been caused by localized heating and/or higher evapotranspiration on raised cement benches.*

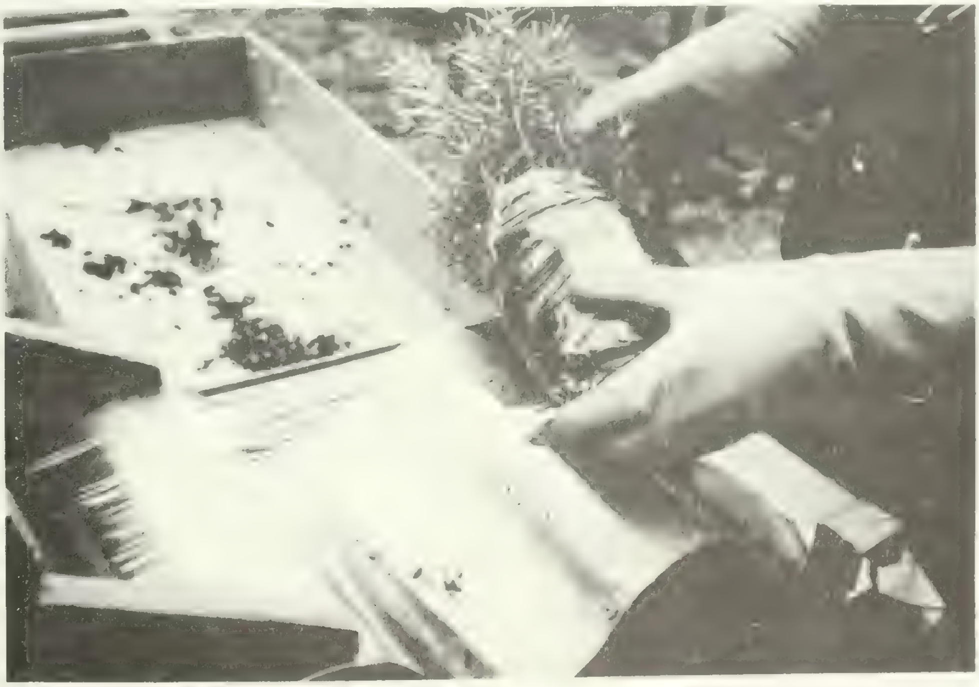
Figure 15-16.—*Food packaging techniques using plastic wrap are easily adapted for transporting containerized stock.*

situations can override these factors. Examples are a source of cheap and plentiful labor, a mandate to employ that labor, a need to reuse containers, a lack of transport vehicles, and an inability of planting crews to cull effectively in the field.

Single cells and book planters are highly adaptive for repacking (fig. 15-16); block systems are less so because of plug extraction difficulties. Complete drenching of containers 2 to 3 days before lifting, without subsequent rewatering, aids lifting. Food wrapping paper and wax-lined cardboard boxes are readily adapted to repacking and transporting forest seedlings. From lifting until planting, seedling protection from sun and wind is essential.

Outplanting success is highest when seedlings are planted quickly. Lifted and repacked seedlings are more susceptible to drying than seedlings left in their original containers. But seedlings transported in original containers damage easily if they are moved to and then held at field sites where watering and protection are less controlled than at the nursery.

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CHAPTER 16

16. MECHANIZED BARE-ROOT PRODUCTION

Advantages and disadvantages of bare-root nursries were discussed in Chapter 9. Because bare-root eedlings take longer to develop than containerized eedlings, considerable more lead time is needed for he production stages shown in figure 5-1. Procedures escribed in this chapter are based primarily on opertional practices used in large commercial pine nursries in the Southern United States (*P. taeda*), Ausralia (*P. radiata*), and Eastern Venezuela (*P. aribaea*). Large scale nurseries are highly specialzed farming operations that use many techniques ommon to cultivating crops. Only generalized proceures are discussed because different types of mahines and tending practices are used in individual urseries over several months (*10*).

16.1 Bed Preparation

16.1.1 Plowing and Disking.—Raised beds usually have less than 0.5 percent slope to minimize erosion; orientation can be east-west for small beds (Chap. 4). Beds are prepared by plowing and disking with tractors. A typical bed is 1.2 m wide and up to 200 m long. Virtually all commercial nursery equipment is manufactured for 1.2-m-wide beds. Since tractor paths are usually 0.6 m wide, only 67 percent of the nursery is actually cultivated.

16.1.1.1 Soil Compaction.—A serious problem in nurseries is soil compaction and its effects on seedling root growth near tractor paths. Compaction forces from vehicles spread out at a 45° angle from the point of compaction. Thus, a wide tire running down a 0.6-m lane can cause compaction effects within an entire 1.2-m-wide bed. One solution is keeping the same tractor paths throughout the life of a nursery.

16.1.1.2 Deep Plowing and Ripping.—Plow pans are frequently created by a plow and undercutting bar passing through the soil over and over at the same depth. Pans restrict root growth and impede drainage. Deep plowing occasionally to 30 cm breaks up plow pans, as does "ripping" with a power-mounted ripper or vertical blade that reaches a depth of 30 to 50 cm.

16.1.2 Fallows and Cover Crops.—Fallow beds must be turned over 4 to 6 months before seed sowing; this allows fallow material time to decompose. Seedling and fallow rotation periods should be such that bed fertility and organic matter levels are maintained. Some nurseries utilize a 2:1 crop to fallow rotation, i.e., 2 years of beds and 1 year of fallow; others utilize a 2:2 rotation. Legume crops are preferred because of the extra N they fix. Sometimes a grass cash crop is grown on fallow land to increase nursery income.

Many nurseries incorporate cull seedlings back into the nursery beds. For best results, seedlings are chopped and turned under immediately. This practice is only suitable for beds that will lie fallow for 1 to 2 years or are being prepared for a cover crop. Chopped seedlings take at least 1 year to decompose into usable organic matter and may harbor disease organisms.

Additional organic matter can be added to beds by spreading sawdust, bark chips, or manure. Manure should be composted to kill weed seeds before it is spread on the nursery bed. All organic matter should be thoroughly incorporated into nursery beds ahead of cover crops and be allowed to stabilize. An overlooked aspect of maintaining high organic matter levels in the nursery is the buffering effect of organic matter on changes in acidity.

16.1.3 Mounding.—Mounding is done with a plow, which throws soil inward from two sides, forming a raised bed about 15 cm high. Beneficial aspects of mounding are: 1) increased aeration in loose soil, which is vital for good root growth; 2) increased drainage that reduces that threat of waterlogged soils; and 3) reduced effects of compaction in the bed itself (fig. 16-1).

Immediately trailing the mounding plow, a roller levels the mound and forms a flat surface. If nursery beds are scheduled for fumigation or sterilization, this is done before mounding.

16.2 Fumigating

When nurseries are highly mechanized, seedling crops are extremely valuable. For example, in the Southern United States, cash value of forestry seedlings may exceed $40,000 per ha. Therefore, managers must pay special attention to control of weeds, nematodes, pathogenic fungi, and soil pests. Steam sterilization of soil is the most effective way to control nursery diseases and pests. But this method is only practical for containerized operations, using small to medium volumes. For bare-root operations, fumigating is just as effective and more practical for large volumes of soil that must be treated.

16.2.1 Methyl Bromide Procedures.—The most popular and effective commercial fumigant for bare-root nursery beds is methyl bromide (table 10-1). It kills most weed seeds, pathogenic fungi, soil insects, and nematodes. Chloropicrin is usually mixed with methyl bromide to increase its effectiveness against soil insects and to act as a warning agent because of its odor and tear-gas effect on eyes.

Methyl bromide is highly toxic. Because it is or- mally applied as a gas mixture, special precau ons are needed to keep the gas in the soil. Gas activ is greater in warmer climates. Because of the di rse climates in tropical regions, suitable application tes must be obtained from local pesticide officers or ti- cide distributors in each country.

The normal method of applying gaseous fumig nts is with chisel plows having injection valves atta ed to plow prongs (*6*). The plow prongs can be adjust to apply gas at precise depths. After the gas is inje ed. the soil is covered with plastic sheeting ≥0.04 m thick by 3.3 m wide. Injection and covering is a s gle mechanized operation for entire fields or on s gle strips. Sheet edges are covered with soil to kee he gas from escaping into the atmosphere and to pre nt the sheets from blowing away. Injection depths sh ld be at least 25 cm. Methyl bromide gas diffuses st readily in dry, loose sand (large pore) soils. Se al factors reduce overall effectiveness of fumigants w soil temperature, high soil moisture, high clay (s ll pore) soils, and high organic matter.

16.2.2 Other Considerations.—Some promi ng soil sterilization research exists with c ar polyethylene sheeting and solar energy. Appare y, success of solar sterilization depends on consecu e, bright cloudless days to create constant high temp a- ture in covered soils. If effective soil sterilization n be obtained by solar energy, significant savings n be expected. Normally, fumigating nursery soi is

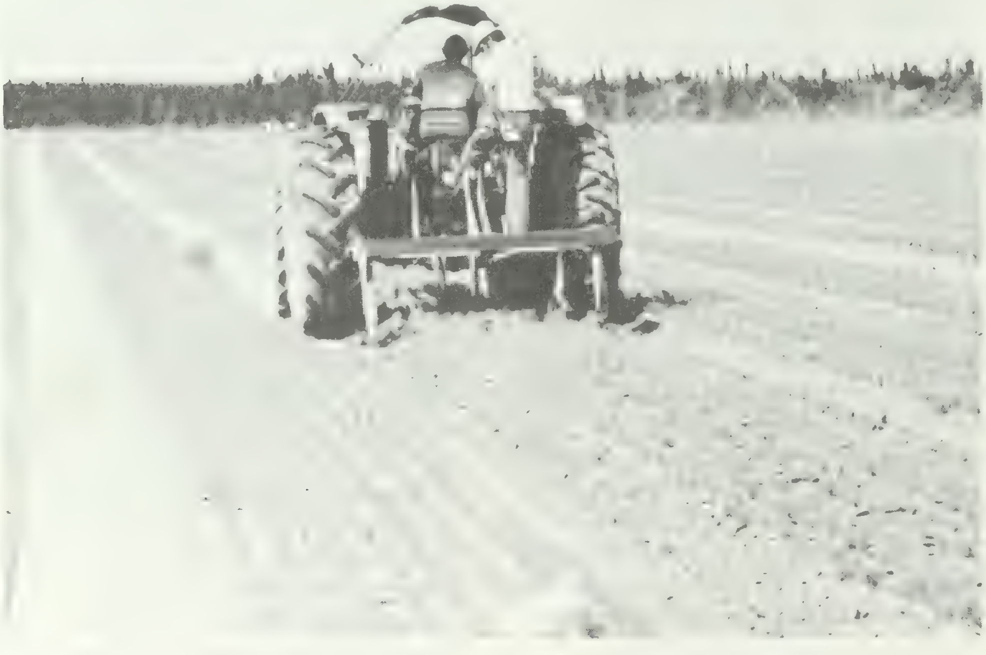

Figure 16-1.—*A hydraulic tractor-mounted blade being used for undercutting pine seedlings on raised or mounded seedbeds.*

quite expensive, as much as $2,900 per ha. Because of his high cost, most managers fumigate only once every 2 or 3 years, depending on seedling/fallow rotation cycles. In some areas, operational fumigation is too costly (*15*).

Soil fumigation reduces or completely eliminates mycorrhizal fungi populations. Thus, following fumigation, one must reinoculate seedbeds with mycorrhizal fungi spores mixed with soil or sand. New commercial equipment can spread a thin strip of mycorrhizal fungi, cultured in vermiculite, in a furrow along with drilled seeds. But a competent machine mechanic can build a suitable spreader for a fraction of the commercial cost.

16.3 Seed Sowing

16.3.1 Sowing Procedures.—Seed sowing is a simple, fairly precise, machine-controlled operation. A tractor-pulled seed drill is adjusted to deliver so many seeds per linear meter. Small plows open furrows immediately preceding drill knives. Seeds are automatically dropped into the furrows, then are immediately covered by a trailing roller.

Seeds are planted at desired depths by adjusting the furrow plow. Periodic checks are needed to assure that the drill is not clogged and is delivering seeds into the furrows. Wrongly assuming that sowing is normal causes unnecessary replanting and germination delays that in turn upset seedling development and scheduled lifting dates. Before they are sown, seeds are sometimes coated with repellents or fungicides (Sec. 16.4.3)

16.3.2 Planting Densities.—Most nurseries grow seedlings at densities of 150 to 300/m^2. At a planting density of 300/m^2, 1 hectare of seedbeds produces about 2 million seedlings, assuming that one-third of the area is non-growing space for alleys, roads, irrigation pipes, etc. Some nurseries use densities of 350/m^2 or greater. However, as seedbed seedling density increases, there is a corresponding increase in cull seedlings. Recently, there has been a general trend to raise seedlings at lower densities of 150 to 200/m^2 (*18*). The assumption is that lower planting densities give individual seedlings more growing space and thus better root systems, i.e., higher quality seedlings.

16.3.3 Mulching.—Immediately after planting, a thin mulch is spread over seedbeds. Mulch provides a protective cover and prevents drilled seed from being washed out by rain. Other benefits of mulch are 1) reduced erosion of the seedbed surface until seedling foliage covers the beds and 2) conservation of soil moisture to aid germination and seedling growth.

Mulches must be non-toxic, biodegradable, and resistant to water droplet impact. Also, they must not stop egress of germinating stems to the surface and should not rot or ferment on top of the seedbed. All mulches must be able to withstand considerable overhead and sideways splash pressure from irrigation systems, even though they are applied as thin layers over seedbeds. Mulches commonly used are: sawdust; grit or sand; vermiculite; chopped, dead pine needles; shredded newspaper; chopped straw or similar agricultural byproducts; chopped pine bark; commercial Hydro-mulch; and rice hulls. The latter are inexpensive and readily available in rice-producing countries.

Managers often hesitate to use mulches, fearing they contain noxious weed seeds or pests. They prefer fresh materials such as pine bark, pine needles, straw, and sawdust. With proper planning, even compost can be used as mulch without fear of harboring pests. Compost pits should be started a year or so before mulch is needed. Compost purity is checked by making weed germination tests before applying mulch. Properly prepared compost mulch (Appendix 13) will not induce nutrient deficiencies or chlorosis in seedlings as it decays.

16.4 Tending Seedlings

16.4.1 Herbicides.—Some people dislike herbicide use in forest nurseries. Alternatives for reducing weeds, complete soil sterilization and hand weeding, have several limitations. Soil sterilization is not always feasible because of costs. Sterilizing or fumigating soils also destroys beneficial microorganisms, including mycorrhizal fungi. Sterilization can even alter soil acidity. Hand weeding is effective but expensive, particularly for a nursery producing millions of bare-root seedlings. Poor supervision of workers and letting weeds get too tall would make hand weeding undesirable for commercial bare-root operations (fig. 16-2).

Preemergent and postemergent herbicides are very effective and cheaper than hand weeding. Table A12-3 (Appendix 12) lists some common herbicides used in nurseries in the Southern United States and Venezuela. The only requirement is that herbicides be non-toxic to the tree species grown.

Some herbicides are toxic for conifers but not for hardwoods, and vice versa. One example is Roundup, which is toxic for *P. caribaea* seedlings. Some herbicides, including Roundup, are extremely toxic to humans and animals. Correct use requires using safety equipment, minimizing unnecessary drift, and timing applications in early morning or late afternoon when winds are calmest. Goal was particularly effective and non-toxic to *P. caribaea* and *P. oocarpa* seedlings at CONARE nurseries in Venezuela. Up to 30-day coverage was obtained; 60-day coverage may be possible with a Goal-Lasso mixture. When postemergent herbicides are not available, mineral spirits or kerosene at $\geq$200 liters per ha kills weeds, does not affect conifers or mycorrhizal fungi, but does kill most hardwoods.

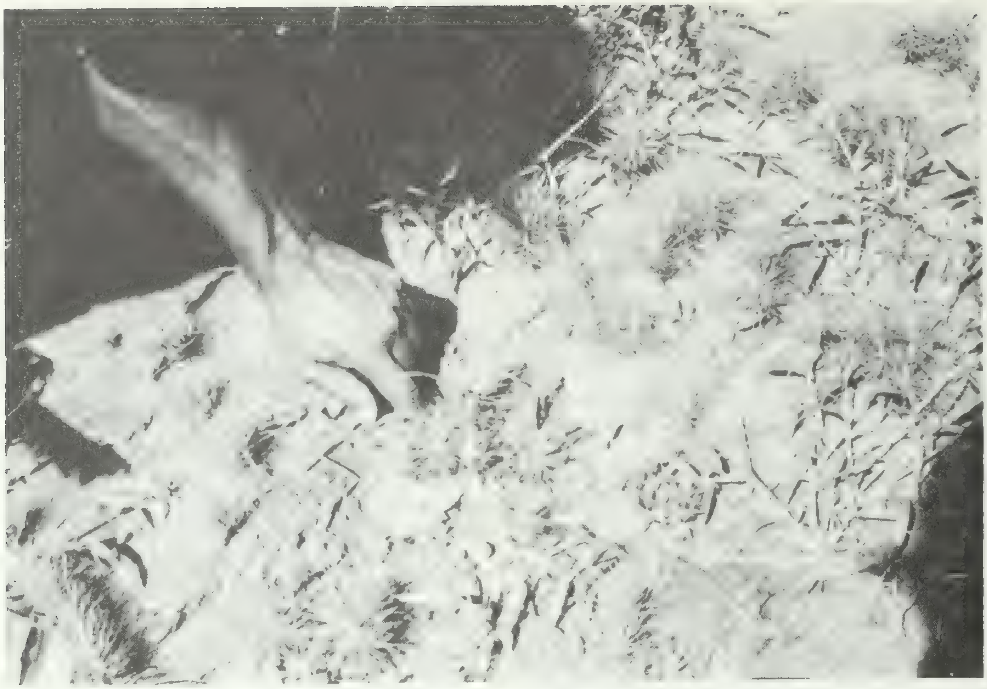

Figure 16-2.—*Hand weeding is too labor intensive and dangerous for most large-scale bare-root operations. If weeds are left too long before being pulled, weed and seedling roots become entangled, making it almost impossible to eliminate weeds without also pulling out seedlings. Uprooted seedlings are seldom replanted correctly, causing high and expensive mortality.*

For most herbicide applications, a tractor is used to pull a high pressure pump and tank sprayer having a 6-m boom-extension pipe system on either side. Before spraying, all nozzles and pipes must be clean and open; cleaning is best done immediately after spraying. Improperly cleaned equipment means clogged nozzles and weed-filled beds that are impossible to clean, even by hand (fig. 16-3). Research control plots not receiving herbicides should always be installed to check herbicide selectivity. To avoid costly mistakes, herbicides are tested on small experimental plots *before* using them on a commercial scale.

16.4.2 Moisture Considerations

16.4.2.1 Watering Frequency.—Seedlings have different water needs and problems at different stages of their nursery development (Appendix 16). When young and succulent, seedlings are watered enough to keep them growing but not so much that beds erode or get damping-off. Thus, young seedlings are checked every day for adequate moisture, particularly at levels 2 to 10 cm below the surface where water is needed most. (*9*)

As seedlings develop, the biggest problem is underwatering. If seedlings are underwatered during periods of normal growth, both overall growth and vigor are seriously affected. Generally, sandy bare-root beds are well drained and difficult to overwater. Exceptions are natural low spots or areas where compaction and plow pans impede drainage. Ab t 3 months before seedlings are lifted and outplan , water is purposely cut back to start hardening f processes.

16.4.2.2 Irrigation Systems.—Several overhead rigation systems exist: mist, continuous spray, pulse, and trickle irrigation (*7*, *8*). Each system advantages and disadvantages, depending on nurs size, type of water available (well vs. far av stream), and available pressure head (natural or m made). Sometimes, water soluble fertilizers can be jected into irrigation water; several injector desi are available (Appendix 16).

Cleaning and maintenance are a must for water system, particularly when natural or added solved salts are high. Salts corrode pipe and mo fittings and clog openings of small-aperture nozzl Failure to clean or replace defective nozzles can ca high mortality in several beds when young seedli are either washed out or dried out (fig. 16-4A). Wa from loose pipe connections can cause large seedl areas to wash away (fig. 16-4B).

Nursery managers must not hesitate to use wat but irrigation water should be considered a supp ment to rather than a substitute for rainfall. Ea watering system should deliver up to 55,600 liters water/ha/day. However, even greater capacity needed because a large part of irrigation water is l

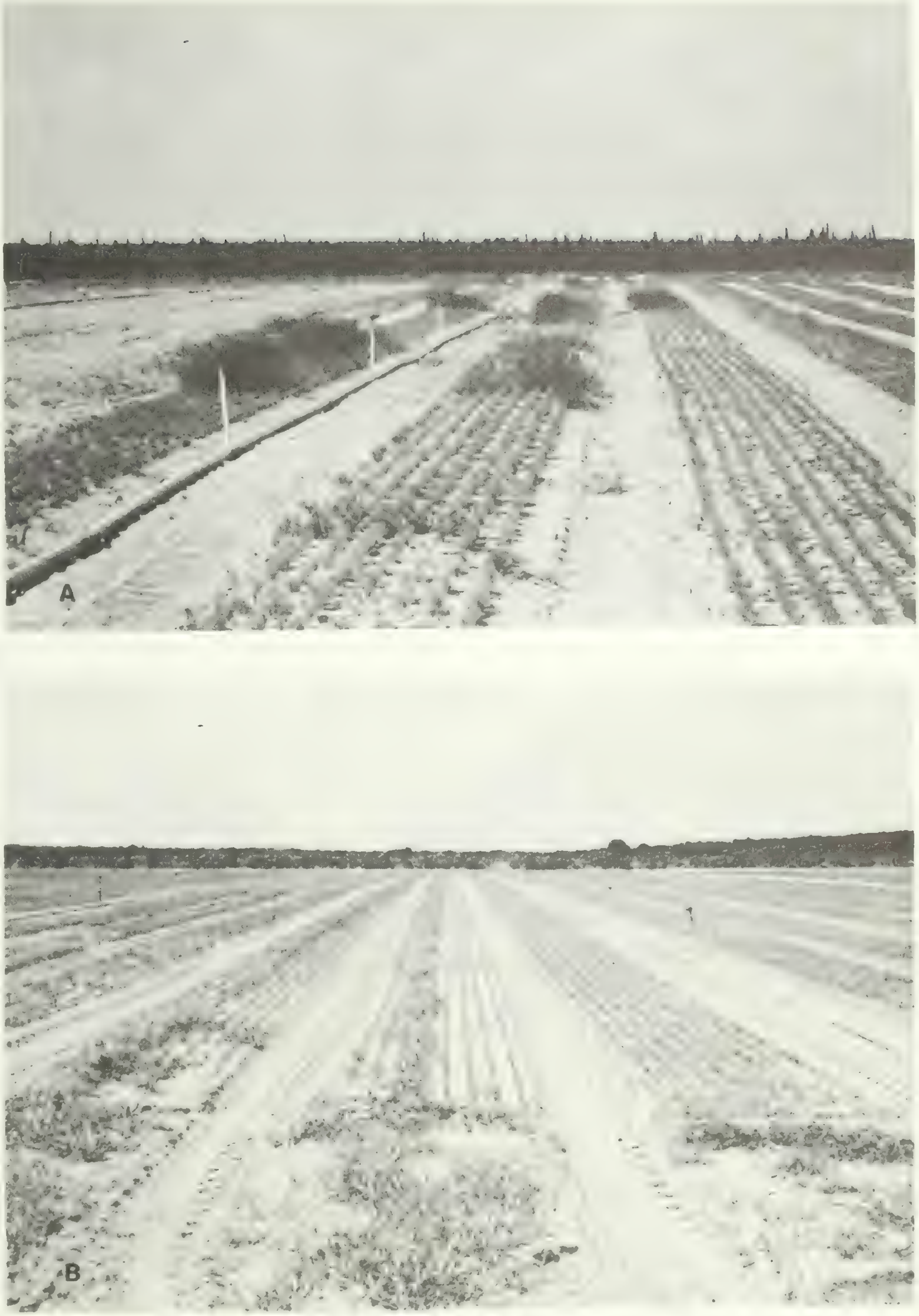

Figure 16-3.—*(A) Weeds out of control in bare-root pine beds. (B) Weed-filled beds caused by improperly cleaned herbicide spraying equipment.*

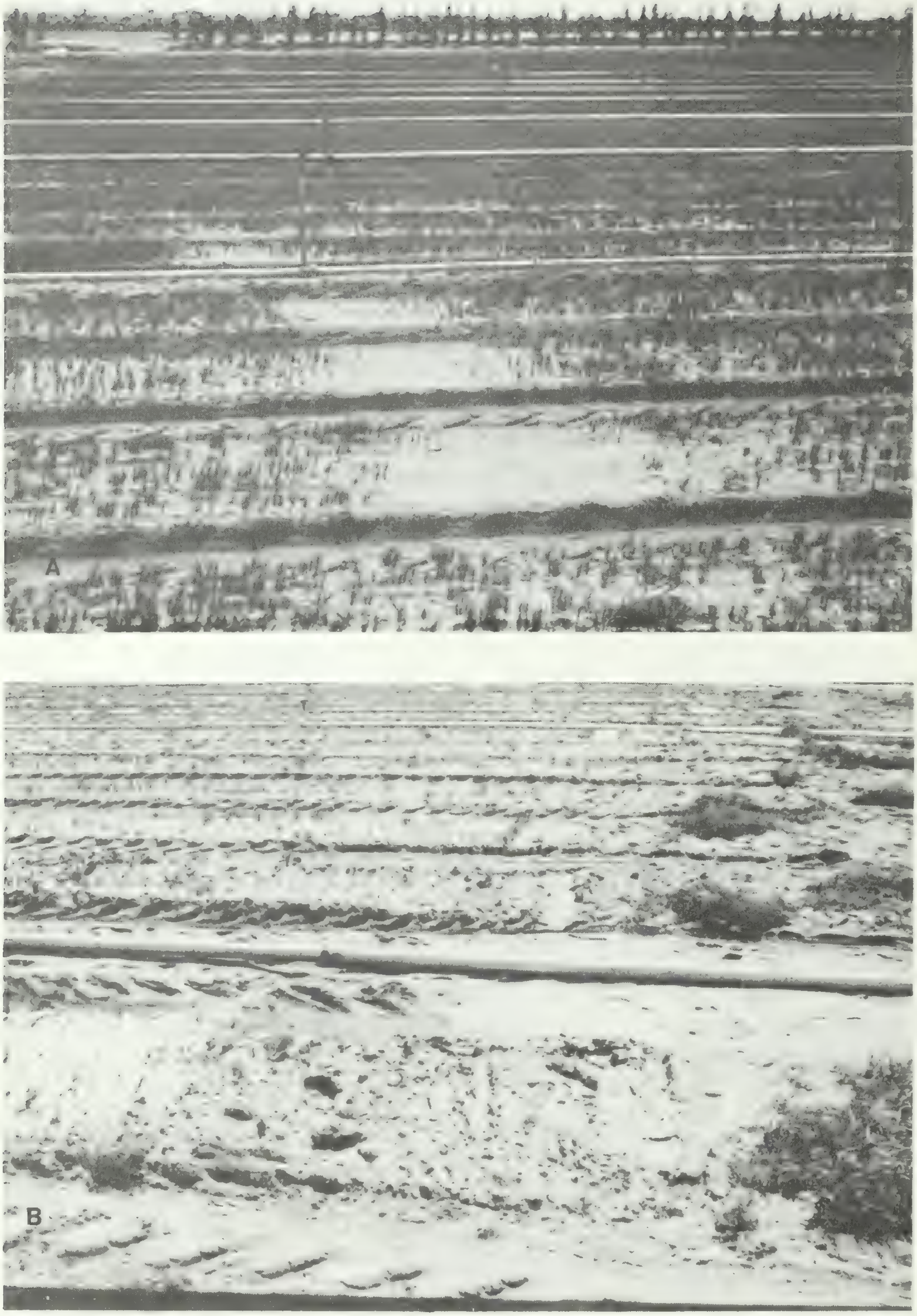

Figure 16-4.—*(A) Unnecessary seedling mortality occurred when water from non-functioning impulse irrigation nozzle washed out seedlings from bare-root pine beds. (B) Just as disastrous and unnecessary seedling mortality occurred when loose pipe connections went unattended for a long time.*

evaporation and runoff; excess watering is also necssary to flush away salts that accumulate at the soil urface from evaporation (*12*).

More detailed information on water schedules, verhead watering systems, and nutrient injector sysems for overhead irrigation are given in Appendix 6.

16.4.3 Repellents and Pesticides

16.4.3.1 Seedcoat Repellents.—Large seeds (e.g., *inus sp.*) are subject to predation by birds, insects, nd mice because of their long germination periods nd shallow sowing depth. Coating or covering seeds ith a repellent such as anthraquinone, a bitter-tastng chemical, discourages predation. The repellent stays on the seedcoat as seedlings germinate, preventng plucking by birds. Combining a fungicide such as hiram with repellents on the seedcoat simultaeously lessens the chance of damping-off and repels nimals.

16.4.3.2 General Pesticide Guidelines.—Selected ursery personnel must be trained to detect insect nd disease problems before serious seedling damage ccurs. Frequent checking of seedbeds helps spot signs f pests or disease (Chap. 12). Appendix 12 summaizes the use and effectiveness of herbicides. Generlly, diseases are more serious than most insect atacks and are much harder to treat and control.

Because of the diversity in local climate, soils, and ree species planted, general pesticide recommendaons are difficult to make. Experienced forest pest pecialists are usually in short supply. But agriculural or horticultural specialists can usually handle most problems because many insect and disease probems affect crops as well as forest trees. Before specific reatments are imposed, nursery managers must be ure that they will not harm mycorrhizal fungi or ther soil organisms. In severe cases, pesticide treatment and subsequent reinoculation with mycorrhizal ungi may be needed.

16.4.4 Fertilizers.—Fertilizers and organic mendments are essential for commercial nursery oprations. Both kinds of nutrient supplements help maintain the nutrition of soils that produce nursery rops for decades, sometimes for a century. Special monitoring of soil fertility, including acidity and soluble salts, is needed (Chap. 13).

Fertilizers can be applied in several ways. For large perations, slow release granules are drilled longside seeds at sowing; they dissolve within 6 to 8 months after application. Water soluble fertilizers an be incorporated into irrigation water, but this echnique is less preferred than incorporating granular fertilizers in seedbeds because it requires more echnical expertise in mixing and maintaining salts t acceptable levels. Specific fertilizer formulations will depend on the recommendations made after soil samples are analyzed.

16.4.5 Inoculation with Mycorrhizal Fungi.—As explained in Section 16.2, soil sterilization controls weeds and harmful soil microorganisms, but it also kills mycorrhizal fungi. If plantations or scattered trees having mycorrhizal fungi exist close to the nursery, reinoculation should occur quickly from wind-disseminated spores. In other areas, particularly where no native pines exist (as in native savannas and grasslands), artificial inoculation is required.

Techniques exist for applying vegetative inoculum with seeds at sowing (Sec. 16.3.1). Usually, spore inoculum is used. The procedure involves collecting duff and topsoil (0-2 cm) from underneath already-infected trees in nearby plantations, bringing the material to the nursery, and grinding and incorporating it in seedbeds. An alternative method is soaking the material in large volumes of water and applying the water containing spores over nursery beds with spraying equipment. Pesticide spraying equipment should not be used unless it is thoroughly cleaned and no other equipment is available. A few seedlings can be lifted at random from seedbeds in 4 to 6 weeks to check inoculation success. If inoculation is unsuccessful, the seedlings have poorer root growth and develop severe yellowing of foliage (fig. 16-5A). Figure 16-5B shows properly inoculated seedlings.

16.4.6 Root Growth Control.—Healthy, well-developed root systems help seedlings maintain vigorous development in the nursery and adapt quickly to new environments after outplanting. Several operations stimulate good root growth and development: wrenching, undercutting, and lateral (side) root pruning. Advantages of maintaining adequate shoot/root ratios are outlined in Chapter 11.

16.4.6.1 Wrenching.—Repeated wrenching is an effective method of stimulating lateral root development in the seedlings of some species, including *P. radiata* (*3*) and *P. caribaea* (*16*).

Wrenching is done with a tractor-mounted blade that moves back and forth under the seedbeds. Forward blade travel is about half that of sideways travel. The wrenching blade is tilted at a 15° to 20° angle, which helps lift-up the soil. Lifting-up and subsequent falling-back of soil on the seedbeds leave many cracks in the soil, providing good aeration in the root zone and resultant bushy root growth. The first wrenching is done about 10 cm below the surface. Subsequent cuts are made at 21- to 30-day intervals, about 15 cm below the surface.

The wrenching blade must be kept extremely sharp for a smooth, clean cut. The first wrenching should be made as soon as seedlings average about 18 cm in height; evidence suggests that lateral root development on the tap root is greatest for young tap root tissue. Thus, if wrenching is delayed too long, the upper part of the tap root is unable to develop lateral roots.

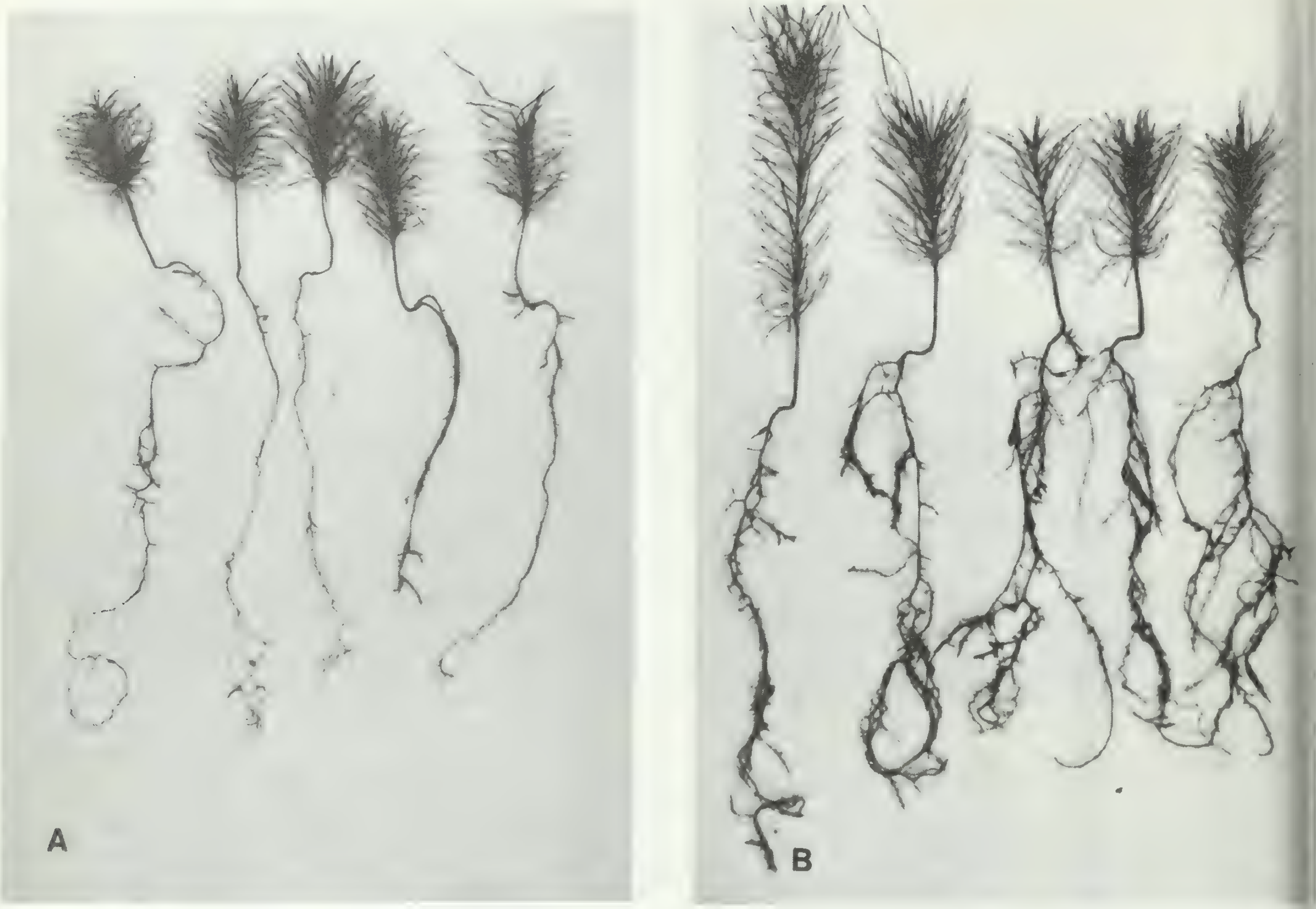

Figure 16-5.—*(A) Uninoculated seedlings.* ***(B) Properly inoculated pine seedlings have visible mycorrhizal fungi-root associations within 4*** *6 weeks.*

Lateral bushy roots that develop after wrenching are very small in diameter and are delicate. Special care must be taken to avoid stripping these 3rd-, 4th-, and 5th-order roots from the seedlings during lifting. To some degree, lateral root pruning negates the benefits of wrenching because a large percentage of the root system is lost in lateral pruning.

Seedlings with large, bushy root systems have high field survival (*15*). Abundant roots formed from wrenching absorb water well and regenerate new rootlets readily after seedlings are outplanted. However, frequently wrenched seedlings have lesser amounts of carbohydrates and lipids than unwrenched seedlings. These "food reserves" may be important for survival of bare-root seedlings, particularly in times of drought stress following outplanting.

16.4.6.2 Lateral Root Pruning.—Lateral root pruning is an operational procedure in which roots growing between seedling rows are severed. Afterwards, it is easier to lift seedlings because the remaining root mass is confined to within the rows. Lateral root pruning is done immediately before lifting. This procedure also cuts down on the time required to separate seedlings during grading and packing.

The most popular method of lateral root pruning is with a tractor-mounted rolling coulter driven down seedbeds with coulter blades between the seedlin rows. Coulter blades must be kept between the row otherwise seedlings will be sliced and destroye There is no evidence that lateral root pruning stimulates additional primary lateral root growth; it doe stimulate secondary and tertiary lateral root branching.

16.4.6.3 Undercutting.—Undercutting stimulate lateral root branching and stops shoot growth *(13, 17* Undercutting is done by pulling a rigid blade with sharpened leading edge that cuts the tap root clea (fig. 16-1). If the tractor speed is too fast and the so is too wet, seedlings, can be pulled underground. Th same problem occurs if the blade is dull or if seedling are too small and have insufficient lateral roots fo anchorage. Failure to lower the blade soon enoug *before* entering the beds causes high seedling losse (fig. 16-6).

Undercutting has some negative aspects. The mos serious problem is the plow pan created by pulling th blade at the same depth. Plow pans impede drainag and may cause J-root-shaped root systems for man seedlings.

The first undercutting is at about 18 to 29 cm belov the surface. A second undercutting is usually sufficient to curb excessive height growth of dominan

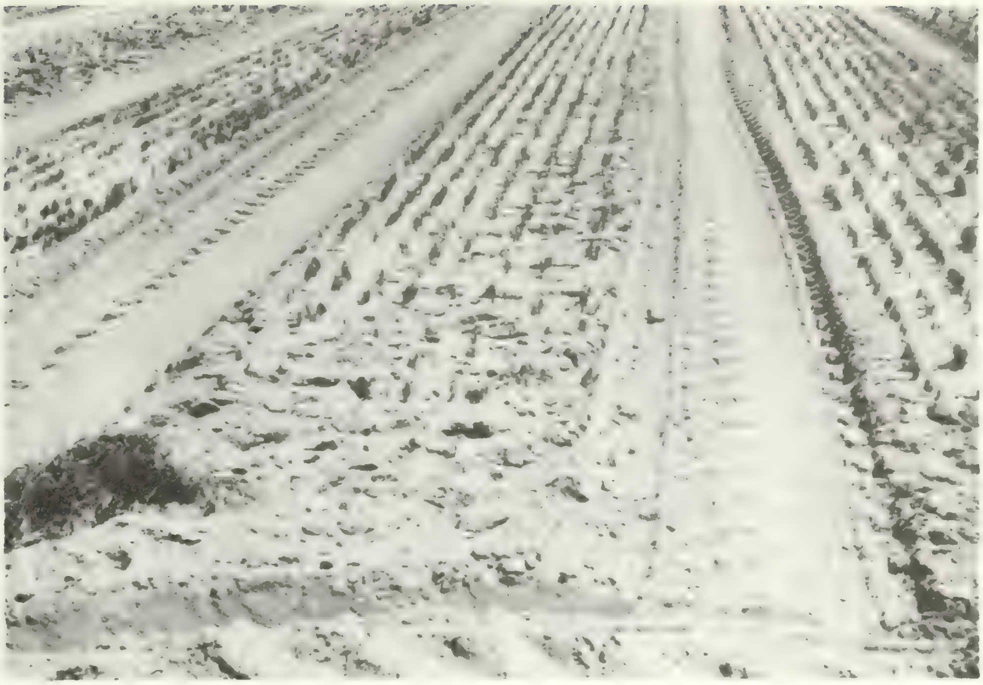

Figure 16-6.—*Undercutting losses in bare-root pine beds when tractor operator lowered the hydraulic blade too slowly.*

edlings. However, if a third undercutting is needed, should be done at least 1 month before seedlings are ted; this gives them time to repair wound damage d to recover from the general shock of large root s.

After undercutting, seedlings should be overwa-red. Because they have lost most of their tap root, ey need excess soil moisture so that the remaining rtion of tap root and the lateral roots can maintain proper water balance in the plant.

16.4.7 Shoot Growth Control

16.4.7.1 *Top Pruning.*—Most conifer seedlings are -pruned after the fifth month, after 30 percent of e seedlings are between 25 and 30 cm tall. Top prun-g slows the height growth of seedlings that threaten suppress slower growing seedlings; unpruned aller seedlings continue to grow *(14)*. The end re-lt is seedlings of more uniform height at lifting. ipped seedlings do not develop new shoot growth for least 3 or 4 weeks after clipping.

Top pruning also fosters a more uniform shoot-to-pt ratio among seedlings. Removing growing shoots m dominant seedlings results in less carbohydrate ansfer to the roots and, consequently, less root owth. Thus, top pruning is a tool for developing edlings of different morphological classes and for creasing root biomass while keeping shoot biomass nstant. Seedling stem diameters also increase after p pruning.

Top clipping is done with flat rotary mowers, sickle-r mowers, and reel-type cutters; all are pulled behind tractors. Problems that arise from top pruning are: 1) seedlings are accidently cut back too short when mowers hit low spots in the tractor paths and 2) wounded stems and needles serve as entry points for disease organisms such as brown spot needle blight.

16.4.7.2 *Hardening-Off.*—Reducing watering frequency in hardening-off slows shoot growth and reduces production of succulent foliage. Hardening-off is needed for both container-grown and bare-root-grown seedlings. A more thorough discussion of this subject is given in Chapter 11.

16.5 Lifting and Transporting

16.5.1 Historical Review.—Lifting and preparing seedlings for distribution is a crucial process. In temperate climates having a well-defined dormant season, seedlings are lifted and stored up to 120 days without excessive loss of vigor. Seedling roots are kept moist, and internal storage temperature is between 0° and 4°C. Survival rates of 80 percent are expected after stored pine seedlings are planted.

Outplanting survival in temperate or tropical climates is closely correlated to 1) adequate soil moisture at the time of planting and 2) adequate root regeneration in the soil before the dry season begins. Thus, it is always best to lift and outplant seedlings early in the rainy seasons *(1, 5)*.

Historically, few bare-root planting operations for pine have been reported in the tropics. Venator and others *(20)* reported that *P. caribaea* var. *hondurensis* was successfully bare-root planted when seedling roots were kept moist, outplanting was done shortly after lifting, and sites had adequate soil moisture at the time of planting. Since the late 1970's, bare-root pine stock has been successfully planted on a large scale (1,000 to 10,000 ha annually) in Venezuela and Brazil. With careful attention to detail, it should be possible to expand bare-root plantings throughout the tropics, for conifers and hardwoods alike.

16.5.2 Lifting.—Lifting operations at large-scale tropical pine nurseries are similar to those used in temperate climates. Seedlings are undercut and machine-lifted with care taken to keep roots moist and shaded from the sun. In Venezuela, lifted seedlings are kept moist in buckets of water, a procedure less messy and more effective than clay-water slurries, sphagnum moss, and other alternatives *(7)*. The crucial procedure is outplanting seedlings *within a few hours after lifting*. This process is not difficult for a large corporation if 1) it has firm control over the entire operation, 2) it can organize and coordinate both lifting and planting, and 3) it has access to good roads.

16.5.3 Grading.—Grading is labor intensive, yet is necessary because evidence shows that larger seedlings outgrow smaller seedlings (*2, 4*). Thus, smaller grade 3 seedlings, following Wakeley's classification (*21*), are inferior and should be culled from the seedling tables.

Some nurseries now grade on the basis of root collar diameters because larger diameter seedlings perform better after outplanting (*19*). Grading by overall size and root collar diameter is much faster than grading by shoot/root ratios and root area indices. Trimming excess lateral and tap roots before packaging is done with machetes and chopping block or hand shears.

Low sowing rates (i.e., low seedling densities) in seedbeds (Sec. 16.3.2) usually result in less intensive culling practices during grading and packaging. Operations that do not cull in the nursery depend on planting crews to cull rejects as they plant. Nursery costs are reduced, but slightly higher planting costs exist because grading is an added step. Field grading must be done by trained, conscientious planters; otherwise, inferior seedlings will be planted, resulting in eventual harvestable volumes that are less than those expected from superior grade seedlings. If costly planting machines are used, nursery grading saves valuable time and money over field grading.

16.5.4 Packaging and Delivering.—If same-day planting is used, time consuming packaging in bales, bags, and wraparound crates is avoided (*11*). Huge metal or plastic buckets and tubs filled with water are used to store seedlings temporarily between lifting/grading, transporting/delivering, and machine outplanting. Throughout lifting, grading, packing, and delivering, seedlings must be protected against exposure to sun and wind, particularly at midday to ea afternoon when the sun is directly overhead. principal safeguard against unnecessary injur planting stock is adequate supervision of workers nursery supervisory personnel.

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Appendices

The Why and How-To-Do-It Section

Appendices are not ordered consecutively but refer to actual chapters where a major topic is discussed. For example, the first is Appendix 4 because shading and nursery bed orientation are discussed in Chapter 4.

Appendix 4

Shading Procedures for Small, Covered Nursery Beds in Tropical Areas

The sun's angle of inclination at a nursery site and the orientation of seedbeds are used to determine shading arrangement. The following example can be used to determine positioning of shade cover over small seedbeds. For simplicity, it is assumed that the sun rises at 6:00 a.m. and is perpendicular to the nursery beds by 12:00 noon, i.e., directly overhead (fig. A4-1). Thus, the sun has moved through a 90° arc in 6 hours at a rate of 15° per hour. The problem is then reduced to one of trigonometry, where the distance of penetration under the shade is:

Depth of sun penetration under overhead shade

$$= \frac{\text{Height of shade above seedbeds}}{\text{Tangent of the sun's angle of elevation}} .$$

Table A4-1 summarizes various penetration distan of the sun for several shade heights.

Puerto Rico lies approximately 18° N. latitude fr the equator. For a short time during the year, the is to the north of Puerto Rico as it changes from 18 23° N. and back again. During this period, maxim shade protection is obtained by tilting the shade r accordingly.

Shade screens should be placed about 1.0 to 1. above 1.0-m nursery bed walls and extend about 0. 0.5 m past bed edges. Such placement allows work access to tend seedlings without much extra effor

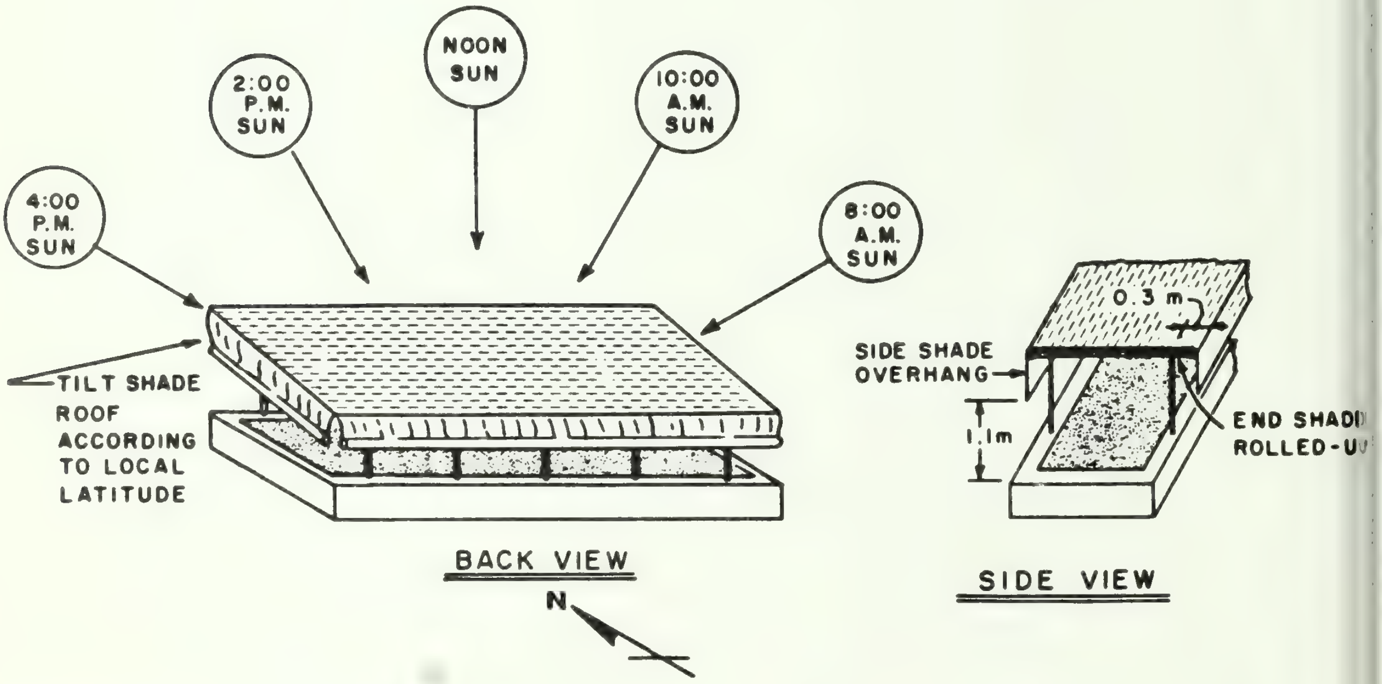


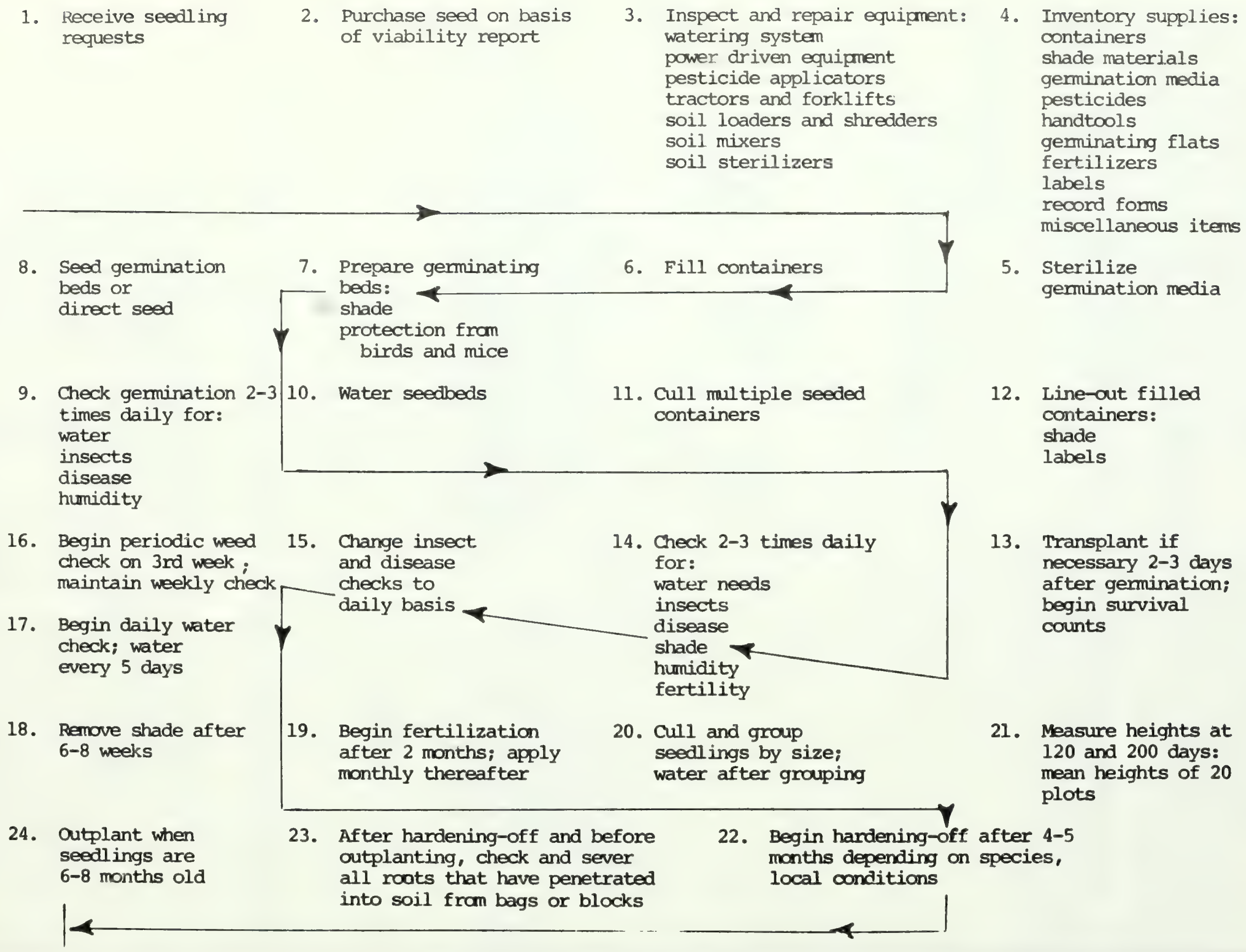
Figure A4-1.—*Small shaded nursery beds in tropical areas are best oriented in east/west direction; shade roof is tilted to sun according to lo latitude (e.g., ± 18° in Puerto Rico). At early and late hours of the day, shade screens are rolled down to keep out low angle ra*

Table A4-1.—*The penetration distance of sunlight under overhead shade for different heights at different hours throughout the day*

Hours		Sun's angle of elevation	Tangent sun's angle of elevation	Depth of sun penetration (m) when shade height (m) is . . .						
A. M.	P.M.			0.6	0.8	0.9	1.1	1.2	1.8	2.1
7:00	5:00	15°	0.27	2.3	2.8	3.4	3.9	4.6	6.8	8.0
8:00	4:00	30°	0.58	1.1	1.3	1.6	1.8	2.1	3.2	3.7
9:00	3:00	45°	1.00	0.6	0.8	0.9	1.0	1.2	1.8	2.1
10:00	2:00	60°	1.73	0.4	0.4	0.5	0.6	0.7	1.1	1.2
11:00	1:00	75°	3.73	0.2	0.2	0.2	0.3	0.3	0.5	0.6

Appendix 5

Flow Chart for Scheduling Mechanized Production of Container Nursery Stock



1. Receive seedling requests
2. Purchase seed on basis of viability report
3. Inspect and repair equipment:
   - watering system
   - power driven equipment
   - pesticide applicators
   - tractors and forklifts
   - soil loaders and shredders
   - soil mixers
   - soil sterilizers
4. Inventory supplies:
   - containers
   - shade materials
   - germination media
   - pesticides
   - handtools
   - germinating flats
   - fertilizers
   - labels
   - record forms
   - miscellaneous items
5. Sterilize germination media
6. Fill containers
7. Prepare germinating beds:
   - shade
   - protection from birds and mice
8. Seed germination beds or direct seed
9. Check germination 2-3 times daily for:
   - water
   - insects
   - disease
   - humidity
10. Water seedbeds
11. Cull multiple seeded containers
12. Line-out filled containers:
    - shade
    - labels
13. Transplant if necessary 2-3 days after germination; begin survival counts
14. Check 2-3 times daily for:
    - water needs
    - insects
    - disease
    - shade
    - humidity
    - fertility
15. Change insect and disease checks to daily basis
16. Begin periodic weed check on 3rd week ; maintain weekly check
17. Begin daily water check; water every 5 days
18. Remove shade after 6-8 weeks
19. Begin fertilization after 2 months; apply monthly thereafter
20. Cull and group seedlings by size; water after grouping
21. Measure heights at 120 and 200 days: mean heights of 20 plots
22. Begin hardening-off after 4-5 months depending on species, local conditions
23. After hardening-off and before outplanting, check and sever all roots that have penetrated into soil from bags or blocks
24. Outplant when seedlings are 6-8 months old

Appendix 6

Non-Oven Procedures for Drying Pine Cones, Mahogany Pods, or Similar Seed-Bearing Fruits at Traditional Nurseries

Ground Drying

Cones, pods, and fruits are spread out on a smooth, dry surface similar to that used for drying coffee beans; radiant energy is used for drying. This method works when seed viability is not appreciably affected by open exposure and when seeds are extremely abundant. Many small, temporary nurseries use this method to extract seeds.

Drying fruits on the ground involves several problems. Rodents and birds can feed on seeds. Protecting seeds requires constant attention by laborers who may be more profitably employed elsewhere. When sudden showers occur, seeds or pods must be picked up and taken into a sheltered area. When several consecutive rainy days occur, mold and fungus can attack bagged moist cones or pods. Likewise, outdoor surfaces must be dry before cones are respread. Finally, cones or pods must be turned frequently so that shaded undersides are also dried. In summary, open-air drying is best only for small seed lots.

Elevated Drying

This method of seed drying is also inexpensive. The equipment used is elevated racks with screen bottoms that allow air to circulate from above and below (fig. 6-1). A hinged top can be added for covering cones or pods during light showers. As soon as the stops, the top can be removed for renewed dry Cones should not be piled more than 4 to 5 layers in such racks. If a solar dryer is available, cones be dried in 3 to 4 days. A small solar dryer is a investment for permanent nurseries.

A complementary method of drying cones or rapidly is placing them on drying racks over a l fire. Empty cones or pods from the previous yea collection can be used for fuel. However, extreme must be used in spreading burning coals unifor under the drying racks to prevent spots where temperatures would roast cones and seeds. As hea air from the fire rises, it passes through the cones dries them. With experience, one can control this k of fire so that air temperature in the area of the co is kept at less than 38°C. Where conditions perm combined use of air conditioning by day and dehum ifying by night will open *P. caribaea* cones within 4 days of storage in office or laboratory buildings.

As soon as cones or pods begin to open, they shou be placed in a large tumbler and rotated until seeds fall out. After falling free from the tumbler, seeds should be dewinged, cleaned, and dried dow a moisture content of 8 to 10 percent and prepared cold storage. Mahogany seeds should be dewinged dried to a moisture content of 10 to 12 percent bef storing under refrigeration.

Appendix 8

Summary of Seed and Nursery Characteristics for Forest Tree Species Commonly Growing or Planted in Tropical and Subtropical Regions[1]

Species	No. seeds per kilogram	Storage recommended	Presowing treatment	Seeding method	Special requirements	Germination and growth
Acacia senegal Willd.	7 to 8 thousand.	None	Boiling water till cool.	Potted or direct sown.	....	No data available on germination. Plantable size in 3–4 months.
Agathis dammara L.C. Richard	16 to 21 thousand.	None	Soak in cold water for 1–2 days.	Potted	Seedlings require shade.	Germinates in 7–14 days. Plantable size in 12–18 months.
Albizia lebbek (L) Benth	1 to 11 thousand.	Ambient temperature for several years.	Boiling water till cool.	Stumps; direct sown.	....	....
Anthocephalus chinensis (lamk) Rich	6 million.	Dry, cold, and airtight for up to 1 year.	None	Potted	Very susceptible to damping-off.	Germinates in 7–14 days. Plantable size in 3–4 months.
Araucaria angustifolia (Bert) O. Kuntze	100 to 200.	None	None	Potted	Require 50% shade.	Germinates in 60–100 days. Plantable size in 21–27 months.
Araucaria cunninghamii Sweet	2.4 to 2.8 thousand.	None	None	Potted	Susceptible to damping-off and requires 50% shade.	No data available on germination. Plantable size in 18–24 months.
Araucaria hunsteinii K. Schumann	1.7 to 1.8 thousand.	None	None	Potted	Require 75% shade in early months.	No data available on germination. Plantable size in 18–24 months.
Azadirachta indica A. Juss	4 to 4.5 thousand.	None	Soak in cold water for 1–2 days.	Potted; stumps; direct sown.	....	Rapid and uniform after 10–12 days. Plantable size in 11–14 months.
Bombacopsis quinatum (Jacq.) Dugand	2.3 to 2.7 thousand.	....	None	Stumps	....	Germinates in 8–20 days. No data on growth in nursery.
Callitris glauca R. Br. ex R.T. Bak et H. G. Sm.	70 thousand.	Dry, cold, and airtight for several years.	None	Potted	....	....
Cassia siamea Lam.	35 to 40 thousand.	Dry, ambient temperature for several years.	Boiling water till cool.	Potted; stumps; direct sown.	....	Good and uniform after 7 days. Plantable size in 10–12 months.
Casuarina equisetifolia L.	700 to 800 thousand.	Ambient temperature for 1–2 years.	None	Potted; bare-rooted plants.	Shade in nursery.	Germination in 40 days. Plantable size in

Cordia alliodora Cham.	1 to 2 million.	Dry, cold, airtight; shortlived viability.	None	Stumps; direct sown.	....	Germinates in 15–30 days. Plantable size in 9–12 months.
Cryptomeria japonica Don.	330 to 400 thousand.	....	None	Potted or cuttings.	Low germination capacity: use large plants.	Germinates in 14–28 days. Plantable size in 12 months.
Cupressus lusitanica Mill. (incl. *C. benthamii* Endl.)	170 to 320 thousand.	Dry, cold, and airtight for several years.	Stratify in damp sand for 30 days.	Potted; bare-rooted plants.	Frost-tender in nursery.	Germinates in 35 days Plantable size in 15–1 months.
Cybistax donnellsmithii (Rose) Seibert	....	Dry, airtight in ambient temperature for up to 1 year.	....	Potted; stumps; bare-rooted plants.	....	Germinates in 12–18 days. Plantable size in 6 months.
Eucalyptus camaldulensis Dehn (Northern Prov.)	700 to 800 thousand.	Dry, cold, and airtight for several years.	None	Potted	....	Germinates in 4–15 days. Plantable size in 4 months.
Eucalyptus camaldulensis Dehn (Southern Prov.)	700 to 800 thousand.	Dry, cold, and airtight for several years.	....	Potted	Early shade beneficial.	Germinates in 4–15 days. Plantable size in 4 months.
Eucalyptus deglupta Blume	1 to 2 million.	Dry, cold, and airtight for 1–2 years.	None	Potted	Susceptible to damping-off. Requires shade.	Germinates in 4–20 days. Plantable size in 3–4 months.
Eucalyptus globulus Labill	120 to 140 thousand.	Dry, cold, and airtight for several years.	None	Potted; direct sown; bare-rooted plants.	....	Germinates in 12–14 days. Plantable size in 4–6 months.
Eucalyptus grandis Hill ex Maiden	600 to 650 thousand.	Dry, cold, and airtight for several years.	None	Potted	....	Germinates in 4–10 days. Plantable size in 6 months.
Eucalyptus robusta SM	500 to 600 thousand.	Dry, cold, and airtight for several years.	None	Potted	....	Germinates in 7–10 days. Plantable size in 4–6 months.
Eucalyptus saligna SM	600 to 650 thousand.	Dry, cold, and airtight for several years.	None	Potted	....	Germinates in 1–20 days. Plantable size in 4 months.
Eucalyptus urophylla S. T. Blake	210 to 300 thousand.	Dry, cold, and airtight.	None	Potted	Good vegetative propagator.	Germinates in 7–12 days. Plantable size in 4 months.

Appendix 8 (continued)

Species	No. seeds per kilogram	Storage recommended	Presowing treatment	Seeding method	Special requirements	Germination and growth
Gmelina arborea Roxb.	700 to 1,400.	Shortlived viability, up to 1 year.	Soak in cold water for 1–2 days.	Stumps; potted plants or direct sown.	....	Germinates in 14–28 days. Plantable size in 6 months.
Leucaena leucocephala (Lam.) de Wit (Hawaiian type)	27 to 30 thousand.	Ambient temperature for several years.	Soak in water 80°C for 2 minutes.	Potted	May require importation of *Rhizobium* strain for nitrogen fixation.	Germinates in 8–10 days. No data on growth in nursery.
Leucaena leucocephala (Lam) de Wit (Salvador type)	26 to 30 thousand.	Ambient temperature for several years.	Soak in water 80°C for 2 minutes.	Potted	May require importation of *Rhizobium* strain for nitrogen fixation.	Germinates in 8–10 days. No data on growth in nursery.
Ochroma lagopus SW	70 to 100 thousand.	Dry, cold, and airtight for 1–2 years.	Boiling water till cool.	Potted or direct sown.	50% shade, but is very susceptible to damping-off.	Germinates in 5–18 days. Plantable size in 3–4 months.
Parkinsonia aculeata L.	12 thousand.	Ambient temperature for up to 1 year.	Soak in cold water for 3–6 days.	Potted	....	Germinates in 10–14 days. Plantable size in 4–5 months.
Pinus merkusii Jungh & de Vriese (Island Prov.)	60 thousand.	Dry for 1–2 years.	None	Potted	No grass stage. Requires mycorrhiza and some shade.	Germinates in 10–12 days. Plantable size in 8 months.
Pinus occidentalis Swartz	35 to 40 thousand.	None	None	Potted	Mycorrhiza required.	No data available on germination. Plantable size in 10–12 months.
Pinus oocarpa Schiede	41 to 55 thousand.	Dry and cold for several years.	None	Potted	Mycorrhiza required. Susceptible to damping-off.	Germinates in 14–21 days. Plantable size in 6–8 months.
Pinus patula Schiede and Deppc.	100 to 140 thousand.	Dry, cold, and airtight for several years.	None	Potted; bare-rooted plants.	Requires mycorrhiza. Susceptible to damping-off.	Germinates in 15–16 days. Plantable size in 6–12 months.
Pinus caribaea Morelet var. *bahamensis* Barr & Golf	80 to 85 thousand.	Dry, cold, and airtight for several years.	None	Potted	Mycorrhiza essential. Susceptible to damping-off.	Germinates in 8–20 days. Plantable size in 5–7 months.

Barr & Golf					damping-off.	5–8 months.
Pinus caribaea Morelet var. *hondurensis* Barr & Golf	52 to 72 thousand.	Dry, cold, and airtight for several years.	None	Potted	Mycorrhiza essential. Susceptible to damping-off.	Germinates in 8–21 days. Plantable size in 5–6 months.
Pinus kesiya Royle ex Gordon	55 to 62 thousand.	Dry, cold, and airtight for several years.	None	Potted	Requires mycorrhiza. Susceptible to damping-off.	Germinates in 15–30 days. Plantable size in 4–6 months.
Pinus radiata D. Don	33 to 50 thousand.	Dry, cold, and airtight for several years.	None	Potted; bare-rooted plants.	Requires mycorrhiza. Susceptible to damping-off.	Germination is rapid and uniform. Plantable size in 24 months.
Prosopis juliflora (Swartz) D.C.	20 to 26 thousand.	Without difficulty at ambient temperature.	Leave in boiling water till cool.	Potted or direct sown.	....	Germinates in 5–6 days. Plantable size in 3–4 months.
Samanea saman Merrill.	4.4 to 7 thousand.	Dry, ambient temperature for several years.	None	Potted	....	Germinates in 14–20 days. Plantable size in 4–6 months.
Swietenia macrophylla King	2 to 2.5 thousand.	Dry, cold, and airtight for up to 1 year.	None	Potted or striplings.	Requires full shade for 2–3 weeks, then half shade for 1 month.	Germinates in 14–28 days. Plantable size in 6–24 months.
Tectona grandis L.	0.8 to 2 thousand.	Dry without difficulty.	Soaking frequently practiced.	Stumps or potted stock.	Several embryos per seed.	Germination often protracted. Plantable size in 12 months.
Terminalia superba Engl. and Diels	5.5 to 6.6 thousand.	Dry, cold, and airtight for up to 1 year.	Alternately wet and dry.	Potted; striplings; stumps.	Requires light shade after germination.	Germinates in 14–50 days. Plantable size in 4 months.
Toona ciliata M.J. Roem var. *australis* F v M	300 to 380 thousand.	None	None	Striplings; potted stock.	....	....

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[1] Adapted from Webb. D.B., P.J. Wood, and J. Smith. 1980. A guide to species selection for tropical and subtropical plantations. University of Oxford, Commonwealth Forest Institute. Tropical Forestry Paper 15. United Kingdom.

Appendix 9

Practical Guides for Fumigating, Sowing, and Transplanting

Recommended Procedures for Use and Storage of Soil Fumigants
Calculation of Materials Required for Producing 1 Million Bagged Pine Seedlings
. Sowing and Transplanting Procedures for Important Species of Tropical Trees
. Publications on Particular Tree Species

I. Recommended Procedures for Use and Storage of Soil Fumigants

GENERAL INFORMATION

Methyl bromine-chloropicrin (MBC) fumigant formulations consistently provide good soil treatment. The two most commonly used forms in forest tree nurseries are MBC-33 (67 percent methyl bromide, 33 percent chloropicrin) and MBC-2 (98 percent methyl bromide, 2 percent chloropicrin). Over 90 percent of all forest nurseries in the Southern United States use either MBC-33 or MBC-2. MBC-2 provides broad treatment of soil fungi, weed seeds, nematodes, and soil insects. MBC-33, on the other hand, is used in specific instances where more resistant root disease organisms occur and where highly susceptible seedling hosts will be grown (*2*).

In large bare-root nurseries, MBC fumigants are usually applied with chisel injectors to depths of 20 to 25 cm. Where soil disease organisms threaten deep-rooted seedling species, fumigants can be injected to a depth of 30 cm or more. Dosage rates for large field applications are 280 to 640 kg/ha.

For smaller nursery operations, MBC or other fumigant mixtures are applied to soil surfaces. The chemicals are released from pressurized containers into evaporating pans placed under polyethylene sheeting. This method is very suitable for treating small seedbeds and transplant beds as well as for fumigating compost medium used in container operations. Dosage rates for bulk materials are 0.59 kg/m^3 for either MBC-33 or MBC-2.

Because of its suitability for small nursery operations, the pan evaporation method is described here in detail, using one MBC fumigant.

DOWFUME MC-2

Although only Dowfume MC-2 (hereafter called Dowfume) is discussed here, most procedures and cautions for its use and storage are applicable to other fumigants (table 10-1). For specific use restrictions and precautions, including toxicity to certain plants or organisms, it is best to consult product labels and current editions of yearly review guides, such as the Farm Chemicals Magazine (*3*) and the Weed Control Manual (*1*).

Dowfume contains methyl bromide with 2% chloropicrin added as a warning agent against overexposure to methyl bromide. When a gas mask is worn, chloropicrin cannot be depended on as a warning agent. Dowfume is applied under a gasproof cover when treating soil and other medium in which seedlings are grown for nonfood and food crop uses.

Dowfume is a liquid under pressure while in container. It turns to a gas when released and mus confined under a plastic or coated fabric gas-p cover. Both liquid and gas forms are poisonous may cause burns on contact. The product label tains detailed instructions for use and handling cautions.

INSTRUCTIONS

Seedbed Soil Preparation

Dowfume is effective only to the depth that so properly prepared. Suitable treating conditions moist, fine, and loose soil having no lumps or cl Soils should be moist but not wet; gas will not spr uniformly through wet soils, and control of weeds soil pathogens will be poor. For best results, fumig to 10-cm depth when soil temperature is above 1 If soil temperature is between 10° and 16°C, *dou the recommended exposure time. Do not fumigat soil temperature is below 10°C.*

Dosage

Determine dosage from information on the prod label. Dowfume controls most weed seeds, nemato and insects present in the soil at time of treatm when used at recommended rates. Certain spe with hard seedcoats may require a higher dosag longer exposure time.

Application Equipment

Materials required include evaporating contain a gas-proof cover of polyethylene or other mate impermeable to Dowfume, cover suppor polyethylene tubing, and an applicator to dispense fumigant.

Dig a 10- to 15-cm-deep trench around the borde the area to be treated; this provides an effective v of sealing the gas-proof cover before releasing the migant. Next, place cover supports at regular in vals on the prepared bed. They must be high eno to hold the cover above the soil surface and evapo ing containers so that fumigant vapors circul freely. Supports must not puncture or tear the co they can be made from inflated polyethylene ba crumpled fertilizer bags, burlap bags stuffed w straw, inverted flower pots, bottles, or cardbo boxes (fig. 9-2).

With the supports in place, evaporating contain are set about 9 m apart in the area to be treated. T containers aid volatilization and uniform dispers the fumigant and keep it from soaking into the ound as a liquid. Pan or basin materials that are ed include glass, porcelain, and tin, but not contain- s made of aluminum or its alloys. Containers should shallow, 4 to 5 cm deep at most; this depth allows ady dispersion of fumigant vapors and assures suffi- ent capacity to hold about a 0.2-liter volume for each 7-kg can of Dowfume dispensed.

After placing the evaporating containers in the ds, a polyethylene applicator tube is fastened to ch, with one end directed into the container. Tubes ould be long enough to allow easy attachment of the migant applicator.

The gas-proof cover is laid over the area to be eated, its edges placed in the trench previously dug, d the edges sealed with earth. Earth should cover e edges to a width of 15 to 25 cm and be tamped wn firmly. During this operation, special care is ken to avoid damaging the cover. Covers will last veral years if handled and stored properly.

Apply Dowfume with a standard opener that punc- res the can, gaskets the opening, and allows the migant to discharge through an attached tube into e confined area being treated. When using any ap- cator, these simple rules should be followed to oid possible contact with Dowfume:

1. Place can in applicator cradle and draw handle quickly toward body of can until piercing point has entered the can and the gasket is seated. Avoid puncturing the can side seam, and keep the point of puncture at the *lowest point on the can* being emptied so that internal can pressure forces all liquid from the can. If the can is punctured high, fumigant vapors rather than liquid will flow through the tubing, and internal pressure will be reduced so that it is difficult to get liquid out of the can.
2. Never open cans without checking that fumigant *will be dispensed where desired*.
3. Do not disconnect the applicator from can or from the polyethylene tubing until can is *completely empty*. The applicator does not have a valve to stop fumigant flow after a can is punctured.
4. If the applicator breaks or fails to puncture and seal a can properly, *keep away from the can* until all the fumigant has evaporated and vapors are carried away.

Only one applicator is needed because it is trans- rred from one polyethylene tube to the next. CAU- ON: Transfer applicator to next tube only *after the n* of Dowfume to which it is connected *is completely pty*. Cans should be warm (15° to 32°C) so that migant flows rapidly through the polyethylene tube to the evaporating container. After application is complete, do not disturb either gas-proof cover or polyethylene applicator tubes because gas may escape and create a hazard to the operator and also reduce effectiveness of the soil treatment.

An alternate method of application involves vaporizing Dowfume before releasing it under the gas-proof cover. This method obtains a uniform concentration of gas throughout the treated area as quickly as possible. Because the fumigant is released as a gas rather than a liquid, evaporating containers are not needed. Dowfume is vaporized by puncturing the can in the conventional manner, immediately turning it upside down, and submerging both the punctured can and attached applicator in hot water. Keep submerged until empty. Additional water, kept hot by a camper's cook stove, should be kept available; the original hot water supply will be cooled by rapid vaporization of the fumigant.

For the vaporization method, openers are designed specifically for a 0.7-kg can and serve both as a can-piercing device and as an evaporation tray. They are used only for soil fumigation *under polyethylene covers*.

Application procedures are:

1. Place tray(s) (one for every 5-m^2 area to be treated) upright on prepared seedbeds. Carefully insert two 0.7-kg cans into nail guides at the bottom. CAUTION: Do not allow nail to puncture can.
2. With tray(s) positioned near edge of seedbed, cover tray(s) and bed with polyethylene, using soil to seal all edges in prepared trenches. Walk toe-to-heal around entire perimeter, compacting solid to prevent wind from breaking cover-earth seal during fumigation.
3. From outside the gas-proof cover, press palm down firmly against each can in turn to puncture it against the nail. Use palm of hand only—*never use* foot, board, shovel or other *hard object that might tear the plastic and permit fumigant escape*. Have masking tape or plastic tape available to repair accidental punctures. Do not attempt to remove trays or cans until cover is removed, after a 24- to 48-hour exposure period. The longer exposure period is needed when soil temperature is *below* 16°C.

Exposure and Aeration

The fumigated area is left undisturbed for the 24- to 48-hour period. Remove cover and let the soil aerate for 24 to 72 hours or more. Work it thoroughly to speed further aeration. Some kinds of seeds can be planted immediately after initial aeration. Sensitive species cannot be planted until after several days of aeration. Do not set out living plants for at least 1 week.

NON-SOIL MATERIALS

Compost and Manure

Follow the general instructions above for soil treatment. Conduct fumigation outdoors or in a well ventilated place. Materials should be loose, moist enough for good seed germination, and at a temperature ≥16°C. For best results, pile the materials ≤30 cm deep on wet ground or on a concrete floor. Piles up to 1 m high can, when necessary, be fumigated if perforated every 30 cm. The cover is supported several centimeters above the material to permit gas to diffuse thoroughly. Dowfume is introduced at the *highest point* of the pile. After exposure, let the pile stand covered for 24 to 48 hours. Then the material is aerated for 1 day, stirred thoroughly, and reaerated 48 hours or longer before using.

Mulches

Straw or hay should be thoroughly soaked several days before treatment. At time of treatment, pile the bales up, cover them with a gas-proof cover, and seal the edges in the same manner as recommended for covering soil.

USE PRECAUTIONS

Dowfume gives excellent results with a wide variety of soils and plants. However, for reasons not clearly understood, plant growth has occasionally been unsatisfactory following treatment. Difficulty has been experienced with carnations, conifers, holly, multiflora roses, snapdragons, and certain other ornamental plants and shrubs. Every grower should experiment on a small scale for at least a full season before extensive use. For best results, observe the following precautions:

1. Do not treat soil when it is cold, wet, or dry.
2. Dowfume is toxic to all plants. Do not fumigate too close to desirable vegetation. Keep edges of the cover at least 30 cm away from roots of desirable plants; water the root zone thoroughly in the area not hooded by a cover. If possible, pre-soak the root zone around desirable plants immediately adjacent to cover to help contain the gas under the cover.
3. Be sure the treated soil or material is free of Dowfume before seeding; working it will speed aeration.
4. Prevent contamination of fumigated areas. Clean shoes carefully before walking from untreated to treated soil. Do not use tools, transplants, or crop remains that may carry pests from nonfumigated areas.
5. Fumigation with Dowfume sometimes slo down the rate of nitrification (the conv sion to nitrates from ammonia by bacte action). Certain ammonia-sensitive plan such as tomatoes, may suffer growth inhi tion when planted in fumigated soils c taining a high amount of ammonia nit gen. To lessen this hazard, at least one-ha and preferably all, of the nitrogen fertili added immediately before or soon after migation should be in the form of nitra nitrogen. This hazard may also be redu by delaying planting until several mon after fumigation.
6. Fumigation of soils high in inorganic matt such as muck, compost, and heavily m nured soil, may occasionally cause con tions of poor plant growth. These so should be fumigated at least 2 months fore planting.

HANDLING PRECAUTIONS

Dowfume (or any other) fumigant is a *highly ha ardous material* and must be handled carefully wh following the precautions given below:

1. Before using, read all label directions and foll them carefully.
2. Do not breathe the vapor.
3. Do not spill. If liquid Dowfume spills on shoes clothing, remove them at once and do n wear them again until they have been air outdoors for several days. Do not we gloves when applying Dowfume because t fumigant can be "trapped" in them, leng ening exposure time to human tissues.
4. Keep animals and children away from plots th are treated and for at least 30 minutes af the cover is removed. The warning agent Dowfume that irritates eyes dissipates i few hours; however, the irritant may n keep children or animals from creepi under the cover.
5. When fumigating inside buildings, keep do and windows open at all times until aerati is completed. Good ventilation is essent for safety and for satisfactory aeration, p ticularly when fumigating compost and m nure.
6. Store Dowfume in a cool place away fr dwellings.
7. Applying Dowfume outdoors often elimina need of a gas mask during application; ho ever, always keep one on hand for em gency use.
8. Always have a helper to assist with applicati and for any emergency that may occur.

II. Calculation of Materials Required for Producing 1 Million Bagged Pine Seedlings

POTTING MEDIUM

In the following calculations, it is assumed that vented plastic bags (20 cm long by 10 cm wide) are used. The first step is determining how many bags 1 m^3 of medium will fill. Flat folded bags (20 by 10 cm) have a circumference of 20 cm (2 by 10 cm = 20 cm). Therefore, the diameter of the filled bag is:

$C = 3.14\,D$, where C = circumference,
$0\text{ cm} = 3.14\,D$ or $D = 20/3.14$, D = diameter,
$D = 6.37\text{ cm}$ and $3.14 = \pi$.

The area (A) of the base (i.e., circle) of the bag is calculated by the formula $A = r^2\pi$. Since diameter equals 2 radii (r), r is determined:

$$D = 2r = 6.37\text{ cm}/2,$$
$$r = 3.18\text{ cm}.$$

Once r is known, the area (A) of the container base is determined:

$$A = (3.14)(3.18\text{ cm})^2 \text{ or}$$
$$A = (3.14)(10.11\text{ cm}^2),$$
$$A = 31.8\text{ cm}^2.$$

Then the volume of the plastic bag (i.e., a cylindrical container) is calculated:

$V = AL$, where V = volume,
$V = (31.8\text{ cm}^2)(20\text{ cm})$, L = length,
$V = 636\text{ cm}^3$ and A = area of base.

One m^3 of medium contains 1 million cm^3. Therefore, the number of bags that can be filled with 1 m^3 is:

$$\frac{1{,}000{,}000\text{ cm}^3/\text{m}^3}{636\text{ cm}^3/\text{bag}} =$$

$$\frac{1{,}000{,}000\text{ cm}^3}{\text{m}^3} \times \frac{1\text{ bag}}{636\text{ cm}^3} =$$

1,572 bags, or 1,570 bags per 1 m^3 of medium when rounded for ease of calculation.

Allowing 15 percent cull mortality, about 1,150,000 filled bags are actually needed to produce 1 million seedlings (see Sec. 5.2.1). Therefore, the total number of cubic meters of potting medium needed to fill the bags is:

1,150,000 bags/1,570 bags per 1 m^3 of potting material = 732 m^3, or 730 m^3 when allowing for waste.

One commonly used pot mix is 5 parts sandy loam soil, 1 part sand ($\geq$1.70 mm sieve), 1 part sand ($\leq$1.40 mm sieve), and 2 parts organic material ($\leq$1.25 mm) such as thoroughly decomposed sawdust, leaves, or agricultural byproducts.

A small quantity of slow-release granular fertilizer (no more than 4 cm^3 per bag) can be mixed into the potting medium to supplement medium nutrient concentration. A 12- to 15-month slow-release formulation will carry over in the field and give seedlings an additional boost. An appropriate volume ratio is 1 m^3 of fertilizer per 200 m^3 of potting medium. Fertilizer should be mixed into potting medium that has been sieved to ensure a complete mixture. The amount of potting medium necessary to fill 1,150,000 bags is broken down into the following components:

$$730\text{ m}^3/9\text{ parts} = 81\text{ m}^3\text{ per component},$$

or

Pot Media Component			*Mix Component Volume*
sandy loam soil	$(5) \times (81\text{ m}^3)$	=	405 m^3
sand	$(2) \times (81\text{ m}^3)$	=	162 m^3
organic matter	$(2) \times (81\text{ m}^3)$	=	162 m^3
fertilizer	$\frac{(1\text{ m}^3)}{(200\text{ m}^3)}\ \frac{x}{(730\text{ m}^3)}$	=	3.6 m^3 (rounded to 4.0 m^3)

The total pot mixture volume needed to produce 1,150,000 seedlings is 730 m^3 of medium + 4 m^3 of fertilizer or 734 m^3.

POLYETHYLENE BAGS

Vented-type bags should be purchased because the small, pre-punched holes in the bag drain excess water. Bags are generally sold in units of 1,000 per box. Therefore, the number of boxes required is:

1,150,000 bags/1,000 bags per box
= 1,150 boxes.

SEEDS

Upon request, seed suppliers will furnish buyers with an estimate of the number of seeds in each kilogram. Most seed dealers also supply area of collection and other seed source information about seeds. The germination information is generally notorized by an independent seed testing laboratory. Assume that *P. caribaea* var. *hondurensis* has 52,800 seeds per kg and that the seed supplier certifies a germination rate of 75 percent. With this information, the seed requirement is calculated. Because of the germination rate of 75 percent, 3 seeds are sown in each bag:

$$\frac{(3 \text{ seeds/bag}) \times (1{,}150{,}000 \text{ bags})}{(39{,}600 \text{ viable seeds/kg})}$$

$$= \frac{3{,}450{,}000 \text{ seeds}}{39{,}600 \text{ viable seeds/kg}}$$

$$= 87.1 \text{ kg of seeds required for all}$$
(rounded to 88 kg).

Only the early germinants should be kept in bag (*4*). Later germinants are thinned out or t planted into bags in which none of the 3 seeds g nated.

III. Sowing and Transplanting Procedures for Important Species of Tropical Trees

The eight procedures described below have worked well at the ITF nursery in Rio Piedras and the Monterrey nursery in Dorado, Puerto Rico. They should work well in other nurseries where similar germination beds and medium are available. In most instances, a local substitute for commercial products exists (e.g., rice hulls for vermiculite and sterilized compost for peat moss). Also, procedures should be applicable to different species within the same genera or same seed type (e.g., *Pinus* sp., tiny seeded species, and species with hard seedcoats needing scarification before sowing).

1. *Pinus caribaea* and *Pinus oocarpa*

Pinus sp. seeds are spread evenly over germination medium at least 10 cm deep. No more than 1,000 seeds should be sown per 30- by 30-cm area of each germination tray. This is a high sowing rate, but less than 70 percent of germinated seeds are usually transplanted. Moreover, because seedlings are transplanted 3 to 6 days after germination, seedbeds are rapidly thinned.

Seeds covered with 1 cm of grit, sand, or vermiculite germinate without difficulty. Unlike for temperate climate pines, seed scarification and stratification are not necessary. Germination bed shade boxes (fig. 5-2) are either hinged or closed securely at the top. Wire screens (1.3 cm square mesh) over the top keep seed predators away. Some nurseries germinate *Pinus caribaea* seeds in the dark. However, we found that 30- to 50-percent saran shade gives excellent germination in Puerto Rico.

2. *Anthocephalus chinensis* (Kadam)

Seeds of this species are extremely small (about 6 million seeds per kg). Care is needed to avoid washing seeds from seedbeds. Seedlings are raised on aerated loose germination medium, preferably sterilized fine sandy loam soil, spread to a depth of 7 to 8 cm in germination flats. A 3-ply layer of tissue paper (pak) is spread over the soil, and seeds are sprinkl top (fig 9-5). The tissue prevents the seeds from ing into the soil.

Kimpak lasts about 2 to 3 weeks before decom tion occurs; the seeds germinate in this period. A light cover (0.3 cm) of fine, dry, sandy loam soil ca sprinkled over the seeds to keep them moist; o wise, exposed seeds will dry out rapidly. White pak material allows control of sowing density b sual inspection because dark seeds contrast against the paper. Kadam germination flats shou watered with a Fogg-it-type nozzle or with over mist sprays. A clock-controlled high pressure mis system works well. The timer is set to spray wate 10 seconds every 30 minutes, the spray rate b adjusted according to ambient humidity. Wate from below also avoids dislodging seeds.

Saran shade (50 percent) is placed 25 to 30 cm a the germination beds. Sides left open allow ligh fall on the flats. A plastic sheet placed about 1 above the flats protects seeds from being dislodge rainfall. Because kadam seeds are small, nei birds nor rodents bother them. Once germination begun, moisture content of the germination be carefully controlled to avoid damping-off.

Proper transplanting time occurs when seedl form at least four small leaves above the cotyled when seedlings are approximately 2 cm h Seedlings are lifted by holding the leaves and pul upwards gently, simultaneously lifting roots f below with a spatula. Because kadam seedlings a very branchy root system, they must be tr planted almost immediately after germinat Avoiding J-roots in transplanting is done by t ming tap and lateral roots to about 3 to 5 cm, pul them through a dish of water, and planting ther containers (Sec. 10.1.1).

Gmelina arborea

The fruit of *Gmelina* is quite large, with 700 or more upes/kg. Seeds are sown with 1 cm of light covering ce hulls, vermiculite, etc.) so that the radicle nerges from the bottom side to prevent J-roots. *nelina* is generally direct-seeded into beds or bags that each seed has a minimum of 6 cm^2 of growing ace. The maximum growing space recommended is to 11 cm^2. Germination medium is kept moist but ll-drained to prevent damping-off.

Since *Gmelina* is generally stump-planted, germi- tion beds having loose sandy soil are ideal for dercutting. A loose soil readily shakes free from ots at lifting. A light shade of not less than 20 per- nt or more than 45 percent is used during germina- n but is removed after 3 weeks. The seeds must be otected from mice and birds.

Swietenia sp. (Mahogany)

Most *Swietenia* seedlings are planted as bare-root ock. The major problem is formation of J-roots. (fig. -1) because of the peculiar method of mahogany ed germination. Seeds should be dewinged and scat- red on top of germination flats or beds, never pushed to the ground with the wing protruding. As germi- tion begins, the hypocotyl emerges opposite the ed abscission scar and turns downward to establish root system. The epicotyl develops from the pocotyl and leaves are formed; cotyledons remain side the seed, which eventually shrivels and falls . Germination medium must be loose, permitting inhibited hypocotyl development.

Dewinged seeds are broadcast on level, well- ained beds. A light covering (about 5 mm) of ver- iculite, fine sand, or rice hulls (never clay soil) is attered over the sown seeds. This cover retains edium moisture around the seeds, avoiding fluctua- ns in seedbed moisture. Saran shade cover (up to 50 rcent) can be used during the germination stage. esh mahogany seeds germinate within 5 to 7 days. edbeds are watered two to three times a day if nec- sary. If sufficient shade is used and if germination edium does not have wide fluctuations in moisture, eds can be sown directly on top of seedbeds without ver.

Eucalyptus

Although *Eucalyptus* sp. are easily regenerated in e nursery, they have small seeds, often more than 0,000/kg. Thus, sowing methods are used that avoid plying too many seeds to germination trays. In one ethod, similar-size sand grains or a dead seed lot are ixed with live seed. The mixture is put inside a salt aker and sprinkled over the germination beds (fig. 5). With practice, workers can develop a fairly uni- rm delivery rate.

In another method, small amounts of seed are aced in a dish. Workers then gently touch the seed with a moistened stick. Generally, two to three seeds adhere to the stick and are placed in containers (fig. 9-5). This process is laborious but fairly effective. After several weeks, the containers are checked for multiple seedlings, and the weakest seedlings are culled.

Following sowing, seeds are covered with a light layer (about 0.3 cm thick) of fine sand or fine vermiculite that is kept moist. Watering is done with a mist nozzle. At least 30-percent, perhaps as much as 50-percent, shade is used to keep germination medium moist and to shield seedbeds of trays from direct rainfall that would dislodge seeds.

6. *Tectona grandis* (Teak)

Teak seeds are difficult to germinate because they are enclosed within an extremely hard seedcoat. Methods to hasten germination are scarification with hot water or sulfuric acid (Sec. 8.1.2). Once the seedcoat is broken, water is taken up and germination begins, being essentially complete within 2 months.

After scarification, seeds are placed in large flats, slightly elevated for drainage, and filled with a 3:1 mixture of sand and loamy soil. The seeds are placed on the bed, covered with a 1.0- to 2.0-cm layer of the same mixture, and then watered. A 30-percent shade keeps beds from drying out. The seeds are sown at a very dense rate of about 200 per 30- by 30-cm area.

Seedlings are transplanted when they have four leaves. They are handled by the leaves, with the roots being lifted out with a spatula. Soil and roots are kept moist between lifting and transplanting. In most countries, seedlings are lined-out in ground-level beds from which they are lifted as stumps and planted. In some countries, because of the way it is field-planted, teak is produced in containers.

In large operations, seeds are sown in drills at 10-cm spacing. As they germinate, they are lifted when ready, and new seeds are dropped into the empty spaces in the rows. This method is inefficient, however, because a large area is used for a small crop, and control of shading and moisture is more difficult.

7. *Leucaena leucocephala*

Leucaena seeds, like those of other legumes, have an impervious waxy seedcoat that must be treated before seeds will germinate. Soaking with hot water (80°C) for 2 to 3 minutes, and additional soaking in water at room temperature for 2 to 3 days, yields up to 80-percent germination.

In nurseries, seeds are sown in germination flats with sand, vermiculite, and soil, about 1,000 seeds per 30- by 30-cm area, and are transplanted to pots. In the field, seeds are direct-seeded on bare mineral soil that is free of weeds. Young seedlings are easily shaded-out by fast-growing weeds. However, once rapid agrowth has started, field-planted *Leucaena* seedlings form a dense mat that shades out weeds and other plants. Inoculation with a *Rhizobium* strain may be needed in areas not planted to *Leucaena* previously.

Stems of old and young *Leucaena* trees sprout vigorously when cut. Several rotations of 5 to 8 years are possible from one root stock. Once vigor is lost, trees must be replaced with new seedlings.

8. *Acacia mangium* (Mangium)

Mangium seeds also have an impervious seedcoat. Soaking in hot water (boiling water just removed from a heat source) for 30 seconds and soaking in tap water overnight breaks the seedcoat. The 30-second
ment time should be followed closely, as we
seed/hot water volume ratio of 1:10.

The seeds are broadcast on nursery beds ar
ered lightly with fine sand or soil. Germination
in 2 or 3 days and is complete in 8 to 10
Seedlings are transplanted to pots when the fir
of leaflets form. Direct-seeding in pots is also po
if seed germination is high. Seedlings reach out
ing size, 25 to 30 cm tall, in 2 to 3 months. Nodu
roots should be visible before outplanting; if not
ulation with a *Rhizobium* strain is needed.

IV. Publications on Particular Tree Species

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Appendix 12

Practical Guides for Using Herbicides and Pesticides

erbicide Information
esticide Information
rocedures for Calculating Solution Concentrations

I. Herbicide Information

GENERAL INFORMATION

When used properly, herbicides control weeds in nurseries where hand weeding is too costly or impractical. The objective is to eliminate competing vegetation that stunts seedling tops and roots, causes uneven seedling growth, and decreases seedling survival per unit area of nursery bed.

Weeds are usually classified as grasses, sedges, or broadleaf plants that are annual or perennial in nature. Some weeds are local problems only, whereas others occur across broad regions, even countries. Left uncontrolled, a single weed species can destroy up to 70 percent or more of plantable seedlings (*5*).

Certain terms are used repeatedly in herbicide use and weed control. Knowing them is essential to understanding how herbicides work and why they must always be considered *controlled substances*. A list of these terms with their definitions is given below (*3*).

Acid equivalent—That portion of a compound or formulation that theoretically could be converted back to the corresponding acid.

Active ingredient—The chemical(s) in a formulated product that is (are) principally responsible for the pesticide effects and that is (are) shown as active ingredient(s) on the label.

Adjuvants—Additional compounds added to pesticides to act as wetting or spreading agents, stickers, penetrants, emulsifiers, etc., to make them easier to handle, mix, or apply.

Broadcast treatment—Applied over an entire area, by ground or aerial means.

Carrier—A gas, liquid, or solid substance used to dilute, propel, or suspend a pesticide during its application.

Concentration—The amount of active ingredient or pesticide equivalent in a quantity of diluent, expressed as percent, lb/gal, ml/L, etc.

Defoliant—A pesticide used for the removal of unwanted foliage without necessarily killing whole plants.

Desiccant—A pesticide used for drying insects or plant leaves and stems.

Diluent—Any gas, liquid, or solid material used to reduce the concentration of an active ingredient in a formulation.

Dormancy—A state of inhibited plant or animal growth.

Emulsifiable concentrate—a pesticide mixture dissolved in a liquid solvent. An emulsifier is included so that the pesticide can be diluted with oil or water and used.

Foliar application—Wetting of foliage with pesticide, usually to the point of runoff.

Formulation—The mixture of active and inert in dients in a pesticide. Some formulations are re for use; others must be diluted.

Frill treatment—Application of pesticide to ne continuous cuts spaced around a tree at a con ient height.

Fumigant—A pesticide used in gaseous form.

Fungicide—A pesticide for control of fungi.

General-use pesticide—A pesticidal product that not cause unreasonable adverse effects on the e ronment when used as directed, and that may purchased and used by the general public.

Granule or granular—A dry formulation of pesti and other components in discrete particles ge ally less than 120 cubic millimeters in size.

Herbicide—A pesticide for control of unwanted ve tation.

Insecticide—A pesticide for control of insects.

Integrated pest management—A process in which aspects of a pest-host system are studied weighed to provide the resource manager with formation for decision making. Integrated p management is, therefore, a part of forest or source management.

Label—The written, printed, or graphic matter on attached to, a pesticide container.

Notch or cup treatment—Application of pesticide cuts spaced around a tree at a convenient heig

Noxious weed—A weed specified by law as being es cially undesirable, troublesome, and difficult control.

Oil—Aromatic or paraffinic oils used as diluents carriers.

Preemergence—Prior to emergence of the speci weed or planted crop.

Registered pesticide—A pesticide that has been re tered with the Environmental Protection Age (EPA) under the Federal Insecticide, Fungici and Rodenticide Act, as amended.

Registration—The process whereby all pesticides registered by the Environmental Protection Age (EPA) under authority of the Federal Insectici Fungicide, and Rodenticide Act, as amended. pesticide labels must have an EPA registrat number.

Release—The process of removing competing vege tion that competes for soil moisture, nutrients, a light with desirable vegetation.

Repellent—A pesticide used to keep animal pe away.

Restricted-use pesticide—A pesticide product for plication only by certified applicators or pers under their direct supervision.

Rodenticide—A pesticide used for rodent control.

Seed protectant—A chemical applied to seeds bef anting to protect seeds and/or seedlings from sts.

factant—A material that favors or improves the mulsifying, dispersing, spreading, wetting, or her surface-modifying properties of liquids.

pension—Finely divided solid particles dispersed a solid, liquid, or gas.

injection—Application of pesticide into the sap- ood of individual trees using tubular injectors.

a low volume—Applications of small amounts of sticide (0.47 to 0.94 liters or less per acre).

tility—The ability of a solid or liquid to evapo- te quickly at ordinary temperatures when ex- sed to the air.

table powder—A finely divided dry pesticide for- ulation that can be suspended readily in water.

ting agent—A chemical that helps a pesticide read and coat (wet) a surface more evenly. It cuts wn on the amount of a spray that rolls off smooth waxy leaves and helps sprays to spread out on airy leaves. Detergents are sometimes used as etting agents.

LANT FACTORS AFFECTING TOXICITY

erbicides are selective or nonselective. Selective ducts are more toxic to some plants than others; selective products kill a broad spectrum of weeds. ause seedlings are plants; weed control usually ers on selective herbicides. Four major plant fac- affecting selectivity differences (*1*) are:

- *Morphological differences*: Factors such as plant size and shape, leaf shape and size, growth stage, presence or absence of waxy and hairy substances, and location of roots close to or well beneath the surface affect contact and absorption of herbicides.
- *Physiological differences*: Internal processes determine whether introduced herbicides are broken down into harmless byproducts or block key processes that eventually cause plant death.
- *Absorption differences*: A combination of morphological and physiological differences allow greater or lesser uptake of herbicide by plant roots and shoots.
- *Translocation differences*: Physiological factors determine whether herbicides are transported with phloem or xylem substances.

ENVIRONMENTAL FACTORS AND TOXICITY

addition to plant factors, environmental factors influence herbicide toxicity (*4*) are:

1. *Atmospheric environment*: Lower air temperatures, CO_2 levels, and barometric pressures reduce herbicide effectiveness.
2. *Soil temperature*: Higher temperatures usually affect overall weed growth and metabolism favorably, increasing herbicide uptake and translocation.
3. *Water*: Higher relative humidity and good soil moisture (i.e., plant not under water stress) increase herbicide effectiveness.
4. *Light*: Changes in photoperiod, light-induced changes in leaf morphology, and photodecomposition of herbicides affect herbicide effectiveness.
5. *Wind*: Physical plant damage by wind and increased transpiration and water stress caused by wind usually increase herbicide uptake.
6. *Microenvironment*: Localized changes in soil pH value, microflora, and fauna affect plant growth and herbicide effectiveness, negatively or positively, depending on the herbicide used and plant grown.

HERBICIDE APPLICATION

Herbicides are seldom sold as pure chemicals. They are formulations of an active chemical plus various additives that allow uniform application. Major herbicide types (*4*) are:

1. *Sprays*:
   (a) *Solutions*: a homogeneous mixture of two or more substances.
   (b) *Emulsions*: one liquid dispersed in another with each maintaining its separate indentity; emulsifying agents are materials sold to help formulate emulsions.
   (c) *Wettable powders*: very finely ground solid particles that are suspended or dispersed in a carrier such as water or oil and sprayed on weeds.
2. *Granules*: Chemicals usually mixed with carriers such as sand and vermiculite and spread by broadcasting over weeds.
3. *Dusts*: Used for insecticides and fungicides but not usually for herbicides because of drift problems.

APPLICATION EQUIPMENT

Sprayers suitable for herbicide application range from small back-mounted tanks (7 to 15 liters) to tractor-drawn boom rigs (200 to 2,000 liters) capable of covering several hectares. For nonselective herbicides, various "rope wick" or "wiper" applicators treat undesirable weeds but protect small seedlings. Broadcast or hand "cyclone" spreaders and tractor rigs are best for granular herbicides. Properly calibrated and cleaned equipment is essential for large and small spraying jobs (fig. 16-3B).

HERBICIDE CLASSIFICATION

The herbicide classifications are technical or nontechnical. Technical classifications use chemical structures and major functional groups at the highest level of categorization; however, such systems are without standardization (*1*). Table A12-1 lists one technical classification, with 16 major categories and specific products under each group.

A more practical, non-technical classification for nursery herbicides is that based on when herbicides are applied relative to seedling germination:

1. *Preplant*: soil incorporated, applied *before* seeding is done.
2. *Preemergence*: applied *after* seeding but *before* germinants emerge from seedbeds.
3. *Postemergence*: applied *after* seeding and after germinants have emerged from seedbeds.

In all instances it is easier to control germinating weed seeds than to control already established weeds with contact herbicides.

Many herbicides have the same major chemical agent but are sold under different trade names, mainly because of different carrier compounds. Some products have been around a long time (e.g., atrazine), others less so (e.g., Goal). Lists go out of date quickly because of changes in product formulation. Keeping this in mind, table A12-2 lists major preplant, preemergence, and postemergence herbicides now used in pine nurseries in the Southern United States and Venezuela.

Table A12-1.—*Technical classification of major herbicide groups*[1]

Herbicide group	Specific herbicide examples
1. Phenoxy compounds	2,4-D; 2,4,5-T; MCPA; silvex
2. Benzoic acids	chloramben (Amiben)
3. Picloram	Amdon
4. Benzonitriles	bromoxynil; ioxynil
5. Bipyridinium salts	paraquat; diquat
6. Amitrole	amerol; cytrol
7. Aliphatic acids	dalapon; TCA
8. Substituted phenols	dinoseb; DNBP
9. Maleic hydrazide	MH
10. Substituted ureas	chloroxuron; diuron, linuron
11. Triazines	simazine, atrazine; prometryn
12. Diazines	pyrazon
13. Amides	diphenamid; propanil
14. Carbamates	chlorpropham; CDEC
15. Trifluralin	Ipersan, Treflan
16. Xylene	dimethyl benzene

[1] Source: (*1*).

Table A12-2.—*Preplant incorporated (PPI), preemergence (PRE), and postemergence (POST) herbicides used in the Southern United States and Venezuela for controlling weeds in pine nurseries*[1]

U.S.A.	Venezuela
PPI	
Eptam	....
Eradicane	....
Sutan	....
Vernam	....
PRE	
Aatrex	Sencor
Lasso	linuron
Sencor	Patoran
Milogard	Dacthal
Princep	Prowl
Surflan	
Treflan	
Caparol	
Enide	
Destun	
Dual	
Devrinol	
Modown	
Goal	
Ronstar	
POST	
Roundup	Diuron
Velpar	atrazine
Poast	Sencor
Attac	linuron
	Mineral spirits

[1] Sources: (*4*), (*2*).

Whenever possible, new products must be tested in replicated nursery trials to detect selectivity traits for forest seedlings and local weeds. For example, one experiment with *P. caribaea* var. *hondurensis* transplants showed that 26-day survivals were better when several herbicides were applied to beds 48 to 72 hours before rather than 24 hours before transplanting (*2*).

SPOTTING HERBICIDE PROBLEMS

Failure to carefully follow instructions on herbicide product labels inevitably causes problems. Some of these and their probable causes (*3*) are:

1. *Poor weed control*: This problem is caused by failure to use selective herbicides for certain weeds and failure to apply herbicides at correct rates, right time, or in the best manner possible.
2. *Seedling injury*: Herbicides are often blamed for injuries that are also caused by insects, diseases, wind, overwatering, nutrient deficiencies, and abnormal weather conditions.

Practices involving herbicides that cause seedling injury are:

(a) Using a herbicide not labeled for a particular tree species;

(b) Failure to clean spray equipment thoroughly, resulting in leftover herbicide being applied to susceptible seedlings;

(c) Planting susceptible seedlings on land treated with herbicide the preceding year;

(d) Using application rates excessive to those recommended;

(e) Improper timing of herbicide application; and

(f) Drift to susceptible seedlings from wind, washing and cleaning equipment, and soil leaching.

To minimize herbicide problems, always read and follow label directions carefully, using only suggested application rates, and *consider herbicides as toxic substances that must always be used under controlled conditions.*

When any chemical application equipment is used, be certain that spray tanks are thoroughly cleaned *before* as well as *after* use. Follow carefully all directions for mixing, applying, and using materials. Empty bags should be burned. All chemicals should be kept in secure storage to avoid accidental injury or contamination of areas surrounding nursery beds and buildings, particularly when nursery facilities are located in watersheds from which potable water is obtained.

II. Pesticide Information

he accompanying list is a generic one because t items are sold under trade names. Package ls must be checked to see if they contain recomded chemicals. The list contains only a very small ber of the control materials available, but it ines those most commonly sold in the tropics.

INSECTICIDES

alathion—widely available, sometimes odorous; ful to control aphids, scales, mealybugs, and some ving insects.

etaldehyde—useful for control of snails and slugs.

icotine sulfate—an old, reputable, and effective rol for aphids and other sucking insects.

thion—useful in controlling leafhoppers, mites, thrips.

otenone—a plant material used both as a contact stomach poison; it has no toxicity to man.

arbaryl—a broad spectrum insecticide; it is exmely toxic to bee populations and should be ided where production hives are located.

MITICIDES

upracide 2E—long shelf life if stored in cool, dry e.

vex—extremely effective, but use requires special e; read label instructions carefully.

hlorobenzilate—used with good results.

FUNGICIDES

Methyl thiophanate—effective for control of soil fungi; used as a soil drench.

Bordeaux mixture—probably the most practical fungicide available. For very small amounts, dissolve 0.1 liter of copper sulfate in 3.8 liters of water by putting the crystals in a cloth bag and hanging them at the top of water in a bucket. Then add 7.6 liters of water and 0.7 liter hydrated lime solution to make 11.6 liters of 11.6 Bordeaux mix. Use immediately because effectiveness is lost if the mixture stands too long. Adding a little soap to the final solution makes it stick and spread better.

Formaldehyde or formalin—can be used on bare ground before planting; it is toxic to plants yet excellent as a preplanting drench to control soil fungi. Its fumes are toxic to people.

Lime sulfur—used to control mildews; it is also a miticide.

Maneb—useful in controlling spot diseases, i.e., leaf spot fungi.

SOIL FUMIGANTS

Ethylene dibromide—an effective soil fumigant that controls soil insects and nematodes. Soil treated with this material cannot be planted for at least 3 weeks because it is very toxic to plants. It is also very toxic to humans. It is sold under a number of commercial names.

Nicotine—sold under several trade names; it is safe to use and effective for soil insects.

SPREADERS

Substances to increase the adherence of sprays to plants. A few shavings of ordinary soap or a small amount of detergent will serve the purpose.

SEED TREATMENTS

Thiram—a wettable powder used as a slurry to coat seeds for protection against damping-off, seed decay, seedling blights, and rodents (table A12-3); it is suggested for conifer seeds.

PREPLANTING BED TREATMENT

Captan—applied to nursery beds before planting to control damping-off; it is worked into the top 8 to 10 cm of soil

Table A12-3.—*Listing of bird and rodent repellents and sti rs used for forest tree seeds in Latin America*

Birds		Rodents	
Common name	Chemical name	Common name	Chemi nam
Repellents			
Anthraquinone	9, 10-Anthraquinone	....	....
Avitrol	4-Aminopyridine	Thiram[1]	Bis (dimet thio- carban disulfi
DRC-1339	3-chloro-p-toluidine hydrochloride	Ziram[1]	Bis (dimetl dithio- carban zinc
Stickers			
Ag-chem activator	....	....	....
Triton	....	....	....

[1] Products registered in the United States by U.S. Environn tal Protection Agency as fungicides only.

III. Procedures for Calculating Solution Concentrations

Often, the nursery technician needs to dilute or prepare a specific concentration of an insecticide, fertilizer, or other chemical. The best way to explain how a specific concentration can be derived from another concentration is to provide an example.

Assume a typical dilution problem where one has 150 liters of an insecticide, previously diluted to 15-percent strength, and needs 435 liters of the insecticide with a final dilution of 4.5 percent. The problem is: How much of the 150 liters must be used to prepare 435 liters with 4.5-percent insecticide? The following formula can be used to determine the correct dilution:

$$C_1V_1 = C_2V_2 \quad \text{or} \quad \frac{C_1}{C_2} = \frac{V_1}{V_2}\ , \quad \text{or}$$

Where

C_1 = concentration of first solution,
C_2 = concentration of second solution,
V_1 = volume of first solution,
and
V_2 = volume of second solution.

Then

$$\frac{4.5\%}{15\%} = \frac{V_1}{435} \quad \text{or}$$

$$(15\%)\ (V_1) = (435 \text{ liters})(4.5\%)$$

or solving for V_1,

$$V_1 = 120 \text{ liters.}$$

Thus, 120 liters of the 15-percent strength inse cide combined with 315 liters of solvent (genera water) will yield 435 liters with a 4.5-percent conc tration of the pesticide.

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Appendix 13

Guides for Applying Fertilizers and Preparing Compost

Important Fertilizer Facts
Procedures for Building a Compost Pile

I. Important Fertilizer Facts

GENERAL

The guides provided here are applicable to traditional and large-scale operations using bulk fertilizers. Greenhouse practices for using soluble fertilizers with irrigation water are more complex. An excellent reference on mineral nutrition in greenhouses is that of Tinus and McDonald (*4*). Since the guides herein are general, caution is needed in their interpretation because soils or local site conditions probably exist for which some guides are not applicable.

DETERMINING FERTILIZER NEEDS

Whenever possible, nursery field test results are compared with known ranges in nutrient levels for various kinds of nursery soils (table 13-4). Where levels are unknown, fertilizer needs are approximated by comparing field test data with "benchmark" low, medium, and high field levels applicable to a wide variety of crops (table A13-1) (*2*).

APPLICATION METHODS

There are four ways of applying fertilizers. Each has certain advantages and disadvantages, depending on type of fertilizer (*2*):

1. *Broadcasting*: uniform spreading of fertilizer over the soil and working it in by machine or with hand implements before seeding. This method gives best distribution of fertilizers to root systems, has little danger of "burning" seedling roots, and is not labor intensive. Disadvantages that usually outweig the advantages are: tie up of soil P and (i.e., makes them less available), ineffecti at low application rates, fertilization of bot weeds and seedlings, and difficulty in ge ting equipment for completely uniform a plication and incorporation.
2. *Localized placement (banding)*: placing fertili ers in bands to the side (5 to 8 cm) or unde (6 to 10 cm) seeded rows. When NPK or and K fertilizers are placed under seede row and trench irrigation is used, placeme must be *under* maximum water height; not, N and K salts move upward by capilla action as soil dries and burn seedli roots—P does not burn. Other disadva tages are: requires special applicatio equipment, cannot be done manually, an fertilizers must be applied before seed germinate. Generally, advantages far ou weigh disadvantages: maximum efficienc for small or medium application rates, min mal tieup of P and K, less feeding of weed than in broadcasting, and best method fo seedlings with small root systems.
3. *Foliar application*: applying nutrients in solution to seedling foliage. The method is suite for correcting micronutrient deficiencies bu not for applying general NPK fertilizer Overfertilizing with NPK can cause foliag burn if excess amounts are not washed of Most foliar fertilizer products are very expensive; discriminate use is the key to effe tive use.
4. *Irrigation water applications*: applying solubl fertilizers in overhead or trench system Methods require special attention, particularly in dry climates where water contain high soluble salts and soil water evaporation is great. Under these conditions, irrigation fertilizer application may be quit wasteful; burning of roots is also a proble when salts accumulate in the root zone.

Table A13-1.—*General field soil fertility levels for agricultural crops*[1]

Element	Low	Medium	High
	Kg/ha		
N	35–55	60–95	100+
P_2O_5	25–35	40–60	70+
K_2O	30–40	50–70	80+

[1] Knowing these "benchmark" field soil fertility levels and the fact that a crop of pine seedlings on sandy soils requires about 1,100 kg/ha of 10-10-10 and 300 kg/ha of ammonium nitrate (*2*), managers can make fertilizer estimates for their nurseries. With experience and record keeping over several years, managers will determine whether benchmark field fertility guides are accurate. For interpreting long-term fertility data, managers should determine a nursery's annual cost of fertilizer, kinds and timing of applications, whether limited capital restricted fertilizer use in any years, and whether fertilizer shortages in any years caused substituting usual products for others.

APPLICATION

General Considerations

For best results, NP and NPK fertilizers are applie at or close to planting time. To reduce N and K leaching, only one-third to one-half of the amounts neede are applied initially. The remaining amounts are applied about one-third and one-half of the way throug the expected seedling rotation.

Placement is at least 7.5 to 10 cm deep and 5 to 7.5 cm to the side of seedling rows. Side placement prevents burning by K and N carried upward in soil capillary water.

Specific Considerations

To prevent volatilization, urea-N is always incorporated in the soil, never broadcast on the surface. Because N is mobile, placement does not have to be as deep as for P. Timing of N application is especially critical when cover crops are incorporated; high C/N ratios will tie up N in decomposition unless fertilizer N is added. If N-fixing seedlings are grown, overall N needs are much less for any nursery soil.

Because P is easily tied up in the soil, it is always incorporated deeply, never broadcast. Major P needs are for good root growth after sowing; later applications are wasteful unless specific P deficiencies are found. Adding N with P aids P uptake by seedlings.

Leaching losses of K are between those of N and P. Efficient applications are those incorporating K at or near sowing. Crop residues are usually high in K.

Sulfur is mobile and readily leached. The major S-bearing fertilizer components used will determine application method and placement. Micronutrient availability is very strongly related to soil acidity. Beyond pH value 6.8, availability of most micronutrients decreases (fig. 13-3).

Effects of Adding Excess Nutrients

Beyond certain concentrations, excess nutrients do nothing to stimulate plant growth. In some cases, excess nutrients actually limit plant growth, usually because of interaction effects (*1*) such as:

- excess K relative to Ca and Mg causing Ca and Mg deficiencies;
- excess P tying-up Fe and Zn and creating deficiencies when they are at borderline soil levels;
- excess Ca relative to Mg possibly creating Mg deficiency;
- overliming causing micronutrient deficiencies; and
- excess soluble Cu and Mn causing Fe deficiencies and vice-versa.

Fertilizer Burn

Excess fertilizer salts in the soil inhibit absorption of other nutrients and cause physical burning (i.e., osmotic desiccation) or death of root tissue when concentrations are very high. When symptoms (leaf or root tips turning brown and drying; visible salts on leaf surfaces) are caught in time, applying excess, unfertilized, irrigation water will wash away these salts. Not all fertilizers have the same burn potential (table A13-2). When in doubt, keep all fertilizers away from direct contact with seedling roots and foliage tissue.

Table A13-2.—*Relative burn potential of different fertilizers*[1]

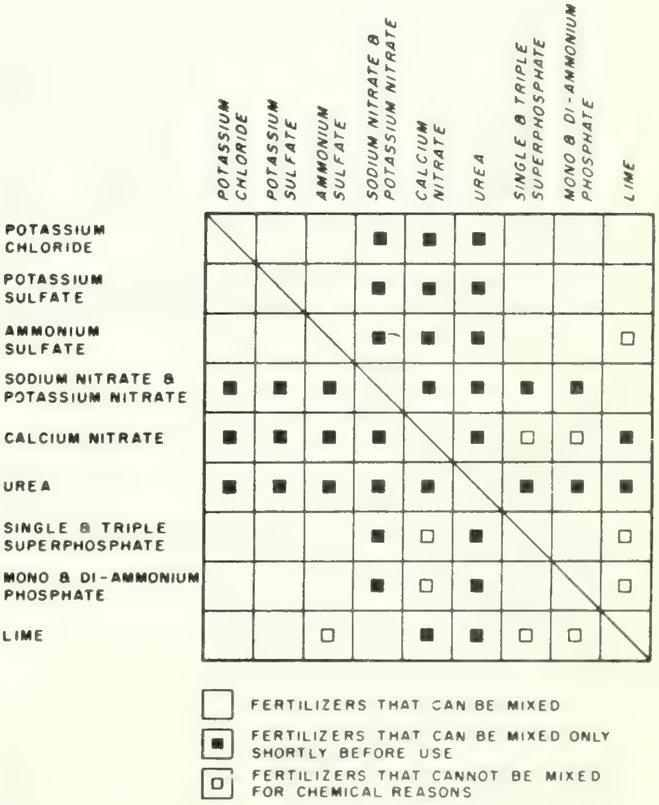
Fertilizer	Formula	Salt index per 9 kg of plant nutrients	
Sodium nitrate	16-0-0	6.0	GREATEST
Potassium nitrate	14-0-46	5.3	
Ammonium sulfate	21-0-0	3.2	
Ammonium nitrate	33-0-0	2.9	
Mono-ammonium phosphate	11-48-0	2.5	
Potassium magnesium sulfate	0-0-22	1.97	
Potassium chloride	0-0-60	1.93	
Urea[2]	45-0-0	1.6	
Di-ammonium phosphate[2]	18-46-0	1.6	
Potassium sulfate	0-0-54	0.85	
Single superphosphate	0-20-0	0.4	
Triple superphosphate	0-48-0	0.2	
Gypsum	....	0.25	LEAST

[1] Source: (*2*).

[2] Urea and DAP may cause more injury than ammonium sulfate because they release free ammonia.

Fertilizer Mixing Guides and Dosages

If lime is mixed with urea or ammonium-N fertilizers, ammonia gas is formed. Similarly, mixing lime with ammonium phosphates, super phosphates, or any fertilizer containing P will make most or all of the P *insoluble*. Other fertilizer mixing incompatibilities are shown in figure A13-1.



	POTASSIUM CHLORIDE	POTASSIUM SULFATE	AMMONIUM SULFATE	SODIUM NITRATE & POTASSIUM NITRATE	CALCIUM NITRATE	UREA	SINGLE & TRIPLE SUPERPHOSPHATE	MONO & DI-AMMONIUM PHOSPHATE	LIME
POTASSIUM CHLORIDE				■	■	■			
POTASSIUM SULFATE				■	■	■			
AMMONIUM SULFATE				■	■	■			□
SODIUM NITRATE & POTASSIUM NITRATE	■	■	■		■	■	■	■	
CALCIUM NITRATE	■	■	■	■		■	□	□	■
UREA	■	■	■	■	■		■	■	■
SINGLE & TRIPLE SUPERPHOSPHATE				■	□	■			□
MONO & DI-AMMONIUM PHOSPHATE				■	□	■			□
LIME			□		■	■	□	□	

☐ FERTILIZERS THAT CAN BE MIXED

■ FERTILIZERS THAT CAN BE MIXED ONLY SHORTLY BEFORE USE

□ FERTILIZERS THAT CANNOT BE MIXED FOR CHEMICAL REASONS

Figure A13-1.—*Fertilizer compatibilities. Taken from (2).*

For small nurseries, application rates are sometimes best expressed as grams/length of row or grams/plant instead of kilograms/hectare. Thus, knowing dosages in terms of tablespoons, handfuls, or other volume measurements is helpful. Converting application rates from a weight to a volume basis is done by determining the density of a particular fertilizer with a scale and calibrated measuring device such as a graduated cylinder. "Relative density" is used because stored, uncovered fertilizers attract water, raising their unit weight. If a fertilizer is suspect being "wet", a sample is placed in the sun for a hours or dried in an oven at 70°C for 2 to 3 hours. measuring device should hold at least 100 cc. weight is then recorded for the amount in the c der. Where scales are scarce, one may possibly b tained from a local pharmacist. With a scale measuring container (graduated cylinder), a si table can be developed that gives the relative de ties of fertilizers (*1*).

II. Procedures For Building A Compost Pile

Compost is made by letting alternate layers of plant and animal wastes decompose in a pile or pit. The end product is a dark, earthy looking humus soil improver. The first step in making a compost pile is to lay out a 2- by 2-m base of organic (high carbon) material, e.g., leaves, rice hulls, sugarcane waste, and crop stubble. Height of the first layer should be about 20 cm. The next layer is a 10-cm covering of high N material, usually fresh animal manure (table 13-10); do not use composted manure. The nitrogenous layer provides N for fungi and bacteria to break down the organic layer. Alternate carbon and nitrogen layers are added until the pile is about 1.5 m high. The topmost layer is a high N one (*1*).

The final compost should have a carbon to nitrogen ratio of between 20:1 and 30:1 (table A13-3). Straw and wood residues usually have too much C compared to N; microbes cannot break down the material. Immature green vegetation has more N than needed, and microbes turn the excess into ammonia gas, which is lost.

As the pile is constructed, each layer is moistened slightly. To avoid washing layers away, water should be applied with a fine spray nozzle. The mix sh feel wet but not soggy.

After the final layer is added, a large depressio made in the center. The depression catches rai applied water to maintain high moisture (abou percent) in the pile. Often the pile is covered wi 15-cm layer of leaves, burlap, or other materia protect it from the wind. It also helps conserve h generated by the micro-organisms, that is necess to kill weed seeds and pest organisms in the pil large pile at least 1.5 m high by 2 m wide at the is self-insulating; any length can be used.

A final but important step is taking daily temp ture readings at the center and edges of the com pile over the first 3 weeks. If temperatures >60°C measured, internal heat of the compost pile has p ably killed decomposing micro-organisms (*3*). W this occurs, the compost pile has "stuck" and mus restored before further decomposition contin Restoring a stuck pile involves complete turnin dissipate heat and provide aeration and reintrodu high N animal-waste layers within the pile.

Since microbes need air, maintaining aeratio the pile is critical for completing the composting p ess. The more often a pile is turned, the faster c posting is completed. Turning a pile one or two ti a week is ideal, but turning it every other wee probably more realistic unless a tractor-mou bucket replaces hand labor in turning. If the method is used, two pits are built; turning invol transferring the pile from the full to empty pit.

An improperly composted pile will not ferment c pletely, and pathogenic organisms or viable w seeds may remain. The problem is corrected by rec posting the material. Contamination with weed s is controlled by using seed-free vegetative mater Length of time for composting is 2 to 6 months. Th fore, composting must be started several months advance of seedling production runs. To test for w contamination, small quantities of compost are u

Table A13-3.—*Carbon-nitrogen ratios of various organic materials*[1]

Material	C:N Ratio
Fresh grass clippings	12
Fresh animal manure	15–20
Clover residues	23
Green rye	36
Leaves	40–80
Sugarcane trash	50
Straw manure	≥50
Corn stover	60
Straw	50–130
Sawdust (rotted)	210
Sawdust (fresh)	400–500

[1] Source: (*2*).

germinate tree seeds; if weed seeds also germinate, e material must be recomposted.

Compost is expensive when transporting compost- g materials is a major cost. Locating a nursery near animal husbandry complex will reduce transporta- on costs and will provide a ready supply of manure. ecause of approximately equal elemental composi- on in animal manures (table 13-10), the authors do t recommend one over another; horse manure has rhaps more fiber content than other manures.

Physical location of a compost pile or pit should be ven special attention because the very nature of the aterials used attracts flies, rodents, etc. Compost ts should be located downwind and far away from e main nursery work area. Although some compost ts are left in the open, placing them under a shelter- use, having a concrete floor and enclosed, rodent- oof fence around it, is preferred. Also, with a con- ete floor, K- and NO_3-rich leachates can be collected d recycled.

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Appendix 15

Specialized Facts for Container Stock Production

List of Container Manufacturers
Five Types of Containers that are Useful in Tropical Countries
Suppliers of Commercial Potting Mixes
Split-Level Nursery Operations for Producing Container Stock

I. List of Container Manufacturers[1]

Supplier	Common name of container	Container material	Biodegradable properties	R eg
Ameripak 806 Central Ave. P.O. Box 8686 Middletown, OH 45042-8686	Ameripak	Polystyrene	No	No
Capilano Plastics Co. Ltd. 1081 Cliveden Ave. Annacis Island New Westminister, BC CANADA V3M 5V1	Capilano Seedling Tray	High density polyethylene	No	No
Castle and Cooke Techniculture, Inc. P.O. Box 1759 Salinas, CA 93902	Seedling tray; plugs	Expanded polystyrene; polyurethane foam	No No	No No
Colorado Hydro Inc. 5555 Ute Highway Longmont, CO 80501	Colorado Styroblock	High-impact polystyrene	No	No
Colorado State Nursery Foothills Campus Colorado State University Fort Collins, CO 80523	Colorado Styroblock	Polystyrene foam	No (reusable)	No
GASPRO, Inc. 2305 Kamehameha Hwy. Honolulu, HI 96819	Hawaii Dibble Tube	Polyethylene	No (reusable)	No
HGP Inc. 761 Kanoelehua Ave. Hilo, HI 96720	Polybag	Perforated plastic bag	Yes	Yes
Hakmet Ltd. P.O. Box 248 Dorion, Quebec CANADA J7V 7J5	Paperpot	Specially-treated paper	Yes	Yes
Jiffy Products of America 1400 Harvester Road P.O. Box 338 West Chicago, IL 60185	Jiffy pots and peat pellets	Molded peat moss	Yes	Yes
Lannen Inc. 2646 Palma Drive Suite 140 Ventura, CA 93003	Paperpot	Specially-treated paper	Yes	Yes
Mansonville Plastics Ltd. 19402 - 56th Ave. Surrey, BC CANADA V3S 6K4	Styrofoam blocks	Polystryene foam	No	No
J. M. McConkey Co., Inc. P.O. Box 309 Sumner, WA 98390	DEEPOT; seedling trays	High density polyethylene	No	No
Plant-a-Plug Systems P.O. Box 1953 Pine Bluff, AR 71613	Styrofoam blocks	Polystyrene foam	No (reusable)	No

I. List of Container Manufacturers—Continued.

Supplier	Common name of container	Container material	Biodegradable properties	Root egress
Leach Cone-tainer Nursery N. Maple St. by, OR 97013	R/L Single Cell	High density polyethylene	No	No
e Technical Products Corp. Cornelia St. sburgh, NY 12901	Multipot	High density polyethylene	No	No
seed Company Box 118 WA 98580	Styroblock	Polystyrene foam	No (reusable)	No
dling, Inc. Highway 41 S Box 238 City, FL 34268	Todd® Planter Flat	Expanded polystyrene	No (reusable)	No
cer-Lemaire Industries, Ltd. 3 - 120 St. onton, Alberta ADA T5G 2Y3	S/L Rootrainer	Polystyrene	No (perhaps reusable)	No
pot Enterprises 2 Harbor Blvd. e 678 len Grove, CA 92640	Treepots; Styrofoam blocks	Polystyrene	No	No
epack East 900 South e 2 Lake City, UT 84111	Tubepack	Polystyrene	No (perhaps reusable)	No
tern Pulp Products Co. 968 allis, OR 97331	Fiber pot	Molded wood pulp	Yes	No (but penetrate pot)

apted from Tinus and McDonald, 1979, and information supplied by Dr. Thomas D. Landis, Region 6, Portland, OR.

II. Five Types of Containers that are Useful in Tropical Countries

ROOTRAINERS

This container was originally called the Book-Planter (fig. 15-6). A new name was adopted after a design change placed grooves along its entire length to eliminate root spiraling. The basic unit is a molded cellulose acetate sheet that folds (as one closes a book) to rectangular, tapered cavities; a single large hole at the bottom allows water drainage. Several cavity sizes are available, as are high-impact styrene trays, each holding 32 seedlings on elevated runners that allow root egress and promote air-pruning of roots. Rootrainers can be reused once or perhaps twice, depending on the handling care they receive and the amount of direct sunlight, which photochemically breaks down the container walls.

Characteristics of this and similar containers are:

Advantages

1. Root development can be checked anytime without destroying roots or seedlings.
2. Ease of handling, since seedlings are carried to the field in the containers.
3. Plugs are quickly extracted.
4. Containers can be saved or thrown away, as desired.
5. If containers are not reused, there is no messy cleaning.
6. Mycorrhizal inoculum can be added directly to roots at any time.

Disadvantages

1. Extra trays are required for handling and shipping.
2. Containers require assembly before filling with medium and seeds.
3. Blank cavities must be reseeded or filled with transplants.
4. If reused, cleaning and reassembling are labor and time consuming.

Outplanting performance of southern pine seedlings grown in Rootrainers has been similar to the performance of those grown in Styroblock containers.

RIGID POLYETHYLENE TUBES

Several rigid design containers are available, the Leach Cone-tainer being the most popular (fig. 15-5). Construction is injection-molded polyethylene, generally reproducible by a local plastics forming industry. Almost any diameter and length combinatio possible. Tubes formed with internal ridges tha vent root spiraling are preferred over those wi ridges. Cone-tainer tubes or cells can be plac racks with holes specially molded to hold ther right. Polyethylene tubes produced for the tr should be treated to resist greater ultraviolet r tion that causes untreated plastic to become br

Other characteristics of rigid tubes are:

Advantages

1. Special racks allow easy handling of indiv tubes and units of 100 or more.
2. Blank cells are easily replaced.
3. Wider spacing is obtained by removing e other cell.
4. There is no root penetration between adja cells.
5. Seedlings are easily removed, culled, and gr into equal heights before being sent to the field
6. Cells are reused for other seedling crops.

Disadvantages

1. Each cell must be handled individually for mal use and recycling.
2. Extracting seedlings is a nuisance, in the n ery or in the field; knocking or kneading of pl cells is often needed for lifting.
3. If seedlings are removed from cells at the n ery, extra packaging is needed to prevent dryi roots and plug breakage.
4. Recycling the cells is labor and time consum

JAPANESE PAPERPOTS

Japanese paperpot systems are used widely in perate zones, particularly for large-scale conifer duction in Finland. Paperpots come in sets of 3 1,400 units; each unit is bottomless and hexa shaped. For production runs of 1 to 2 mil seedlings, capital outlay is small and hand lab adequate for filling and handling. For production as large as 10 million seedlings or more, equipm for complete mechanization should be purchased

Paperpot systems use glued bio-degradable pa Sets are shipped as flat packages that expand int upright honeycomb for filling in special trays. T are joined by water-soluble glue, allowing separa at planting. The paper itself has plastic fibers chemicals to increase container durability. A la variety of diameters and lengths are available. Pa

s are one of the few containers for which a complete
e of handling, filling, sowing, and planting equip-
nt can be purchased. Six people can fill and seed up
2 million pots per day.
haracteristics of paperpots are:

vantages

. Connected tubes are easily separated for plant-
.
. There is a wide range in size and number of
bes in unit packages, allowing wide choice of con-
ner volume.
. Seedlings are carried to the field in the pots;
us, the root systems are protected from damage and
ying.

sadvantages

. Roots frequently penetrate adjoining tubes,
king separation at planting difficult.
. Tube paper can break down too soon, making
ndling and transporting difficult.
. Paper degrades slowly in the field, slowing root
ntact with soil around planted tubes.
Overall, timing of lifting is critical for paperpots to
event overdevelopment of root systems in the nurs-
y and break down of pots. Southern pine seedlings
own in paperpots have generally had lower field
rvival and slower growth after outplanting than
edlings grown in other containers (*1*).

STYROBLOCKS

The original container was made of molded styro-
am, with 80, 135, 160, 192, or 240 cavities per block
flat. Cavity volumes range from 40 to 125 cm^3 and
pths from 10 to 20 cm. Interior surfaces of individ-
l cavities have a special glaze that protects against
ot penetration. Internal ribs orient root growth
wnward and prevent spiraling. Runners on block
ttoms elevate them and promote air-pruning. Some
dels have “fences” around the top edges to prevent
ter runoff (fig. 15-4).
The 80-cavity block may be more suitable for the
opics where large seedlings are needed. Venator and
driguez (*3*) recommended that pine seedlings be
own in low density blocks; however, Walters (*4*)
und that higher density, 192-cavity blocks were ad-
uate for producing large hardwood seedlings in
awaii. Styroblocks are expensive, but if the blocks
n be reused two to three times as claimed by the
anufacturer, unit seedling cost will be substantially
wer. Blocks are reusable until glaze coating on the
ner surfaces is worn away by microbial activity or
eathering. Seedling roots tend to grow into Styro-
ocks without the glaze coating, and it is impossible to remove seedlings without stripping roots. The glazed surface can be protected by washing blocks immediately after extracting seedlings and storing the blocks under shade.

Equipment to fully mechanize Styroblock production systems is available. Simple, low-cost flat fillers, seeders, grit loaders, etc., are available that allow workers to fill and direct seeds up to 300,000 cavities per manday of work.

An older product, Todd Planter Flats (fig. 15-2), is also made from styrofoam and is now adapted for forestry as well as vegetable nurseries (*1*). Cavity openings in this container are square at the top and taper to a small hole at the bottom.

Characteristics of Styroblocks and similar containers are:

Advantages

1. Cells are unitized in rigid but lightweight blocks that are easily transported to remote planting sites, even when filled with seedlings.
2. Block material insulates seedlings from temperature extremes.
3. Blocks can be reused if handled, cleaned, and stored properly, reducing unit seedling costs over long periods.
4. Glaze coating prevents root penetration of adjacent cells and aids in lifting seedlings out of blocks.

Disadvantages

1. Empty cells must be reseeded or transplanted.
2. Difficulties in seedling extraction will occur if pot mix and moisture are not well controlled and if the glaze deteriorates.
3. Damage to a block beyond a certain amount means losing the entire block, even though some cells are intact.
4. Recycling is labor and time consuming.

Styroblock-produced seedlings usually grow better under stress conditions than do those grown in paperpots and other tubes. Outplanting performance of seedlings from Todd Planter Flats may even surpass that of seedlings from Styroblocks. This is presumably so because the strongly tapered configuration of the plug promotes rapid root egress once plugs come in contact with surrounding soil (*1*).

POLYPOTS

These are rectangular containers, smaller versions of the familiar paper milk cartons, manufactured by laminating polyethylene onto both sides of cardboard. Drainage holes are punched before Polypots are cut to size. Their major drawback is that they must be hand-folded and placed in trays before being filled. If laminating is adequate and handling of individual pots is minimal, Polypots last 12 to 14 months in nurseries before disintegrating. There is no available equipment for mechanized filling and seeding of these pots. However, a good machinist should be able to construct satisfactory equipment cheaply with local materials.

Overall characteristics of Polypots are similar to those of Japanese paperpots. Other features are:

Advantages

1. Most countries have local capability to manufacture Polypots in all sizes.
2. Close nesting in trays prevents inter-cell from filling with soil in which weeds can grow.

Disadvantages

1. There are no internal ribs to prevent root sp ing.
2. Air-pruning is impossible unless trays are vated.
3. Roots frequently entwine between pots via holes.
4. More medium is required for filling than other, similar-length containers having modera strong taper.

III. Suppliers of Commercial Potting Mixes

Agritec Co., Inc.
939D Milwee
Houston, TX 77018
(synthetic soils, plant starter blocks)

J-M Trading Corporation
307 S. Lawndale Avenue
Chicago, IL 60623
(HECO soil replacer)

Jiffy Products of America
P. O. Box 338
West Chicago, IL 60185
(distributor of Jiffy-Mix, Jiff-Mix Plus, Grower's Choice, and Magamp products)

McConkey Co., Inc.
P. O. Box 309
Sumner, WA 98390
(perlite, soil conditioners, and fertilizers)

Sierra Chemical Co.
7650 Sycamore Street
Newark, CA 94560
(Osmocote slow-release fertilizers)

A. H. Hummert Seed Company
746 Chouteau Avenue
St. Louis, MO 63103
(prepared pot mixes, vermiculite)

E. C. Geiger Company
Box 285, Route 63
Harleysville, PA 19438-0332
(general nursery supplies and equipment)

Griffen Greenhouse Supplies, Inc.
6 Interstate Avenue
Albany, NY 12205
(general nursery supplies, including irrigation eq ment)

IV. Split-Level Nursery Operations for Producing Container Stock

n split-level operations, gravity feed is used when er possible to compliment semi-automatic mechani equipment. Such a setup reduces energy expenses ile reducing need for additional operators and ma nery. Efficiency of operation may be somewhat ver for split-level operations than for fully mecha ed operations. Yet some countries prefer less mech zed operations that require lower establishment ts, less time to repair when machinery breaks vn, and fewer problems in finding workers who can rate the equipment. A key feature of any semi chanized operation is a tractor-mounted loader ving a capacity of at least 0.5 m^3. End loaders are cient for loading heavy soil and sand into the soil ve and for moving sieved potting medium into the xer (fig. A15-1). Mixers should have a capacity of 2 .

fter a proper soil mix is prepared and dumped m the mechanical mixer, the end loader scoops up mixture and fills each available hopper. Hoppers uld be filled early in the morning before the labor (bag fillers) arrive or late in the afternoon, after workers have left. Hoppers are easily designed to hold 1 to 1.5 m^3 of pot mix. These amounts give bag fillers a full day's supply of mix in their respective hoppers.

Most bag-filling operations in tropical nurseries are run on an incentive basis. A particularly effective method is to employ women on a part-time basis. Since most women have domestic chores at home, they are particularly eager to leave early in the afternoon. If a set price is arranged for emptying a single hopper load, worker morale will be high. In a trial in Puerto Rico, a nursery manager told bag fillers they were free to leave after they had filled 800 bags. Not surprisingly, what was previously an 8-hour task was accomplished in about 6-hours. Other nurseries have effectively employed a fixed price per filled bag. This allows individuals who wish to earn extra money to do so. What should be avoided is a fixed daily wage without any control over production output. Such a policy usually causes a serious work backlog that slows other operations.

From time to time, a quick check is necessary to determine whether the mechanical mixer is mixing

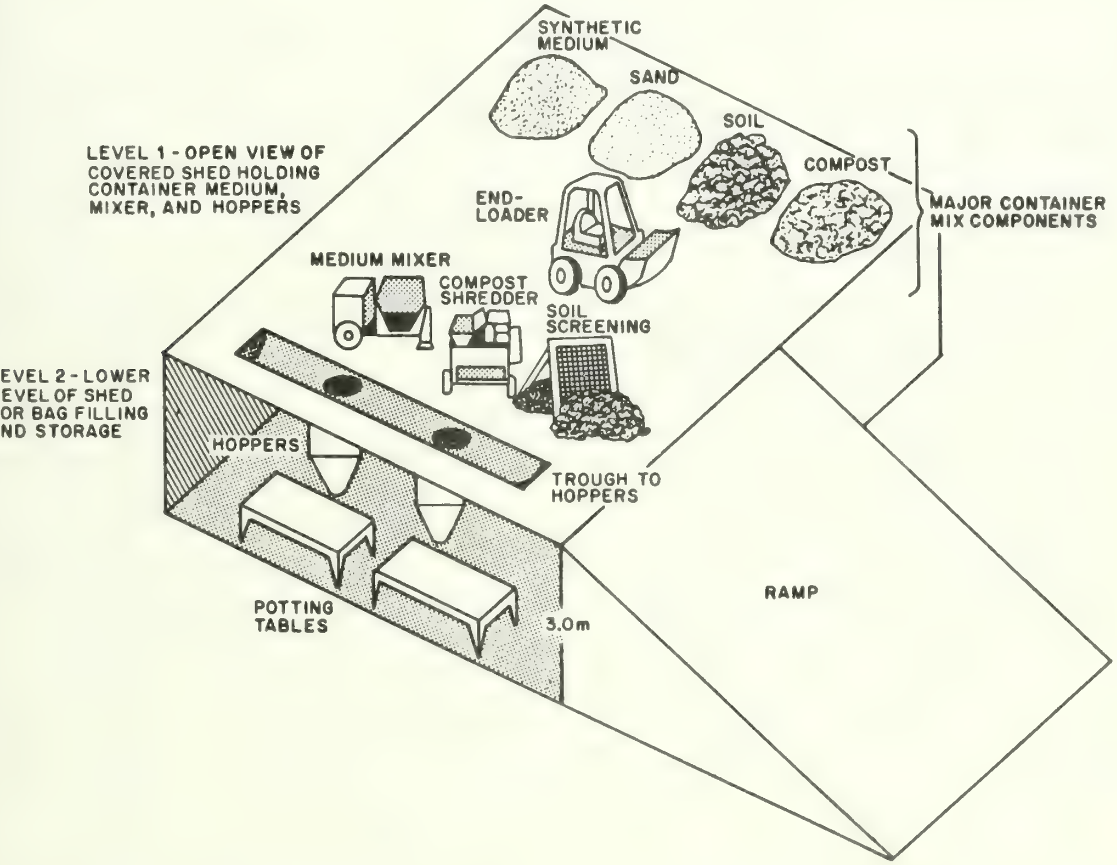
SYNTHETIC MEDIUM
SAND
SOIL
COMPOST
MAJOR CONTAINER MIX COMPONENTS
LEVEL 1 - OPEN VIEW OF COVERED SHED HOLDING CONTAINER MEDIUM, MIXER, AND HOPPERS
END-LOADER
MEDIUM MIXER
COMPOST SHREDDER
SOIL SCREENING
LEVEL 2 - LOWER LEVEL OF SHED FOR BAG FILLING AND STORAGE
HOPPERS
TROUGH TO HOPPERS
RAMP
POTTING TABLES
3.0m

Figure A15-1.—*Overhead view of split-level structure used in producing container nursery stock with semi-automated procedures. Natural topography was used for best placement of structure and approach ramps.*

soil components in desired ratios. A simple sampling method is to pull out about 3 to 4 liters of the mixture and sieve it by hand. This procedure is repeated several times and an average computed. If computed ratios deviate excessively, mix proportions must be adjusted accordingly.

As bags are filled, they are placed in trays (with a capacity of 35 to 45 bags) and loaded onto pallets. Filled pallets are transferred to a flat bed wagon, taken to nursery beds, and off-loaded; workers line-out bags in rows. This operation can also be done mechanically by placing filled trays on roller conveyors and pushing them to a worker who removes the trays and loads them onto a wagon.

Often, natural terrain of a nursery allows construction of a split-level structure. If not, a simple ramp and elevated floor can be constructed by backfilling behind a fence (fig. A15-2).

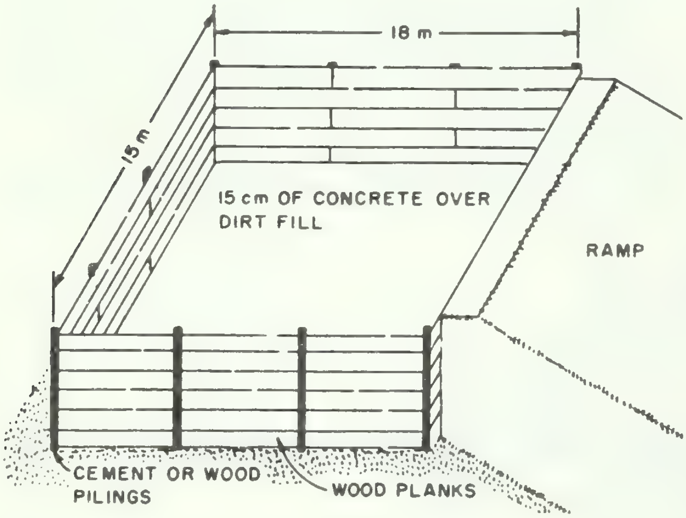

Figure A15-2.—*Split-level structures can also be built on level terrain by filling in a fenced area behind pilings and screen, and hauling in fill dirt for approach ramps.*

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Appendix 16

Practical Guides on Watering and Soluble-Fertilizer Application

I. Watering System Alternatives for Forest Nurseries
II. General Management Scheme for Watering Nursery Seedlings
II. Injector Alternatives for Soluble-Nutrient Watering Systems

I. Watering System Alternatives for Forest Nurseries

Many traditional nurseries and almost all mechanized nurseries have overhead watering systems. Systems with automatic controls save labor and provide dependable water delivery. A multiple water station arrangement, controlled from a single panel, allows one to direct water to some nursery areas but simultaneously to exclude it from others. This feature saves water and maintains flexibility within the nursery complex.

Commercial nursery supply catalogs should be consulted *before* any system is installed. Three general types of water delivery systems are: mist, continuous spray, and impulse (*3*). The mist system delivers a very fine, uniform water coverage as long as strong winds do not blow the mist off designated beds. Mist irrigation is ideal for germination flats because the fine water drops do not pack germination medium or wash seeds from the flats. Mist systems require about 280 to 350 g/cm^2 of water pressure for each nozzle. As many as 100 mist nozzles can be operated on one water line if booster pumps and tanks are used to increase water line pressure. Booster pumps are more economical to operate than elevated water-storage tanks that have a high pressure head of water.

Continuous spray nozzles have larger openings and deliver more water in a given time period than mist nozzles; they also cover larger areas. Thus, they tend to clog less than mist nozzles, are easier to clean once clogged, and water droplets are less likely to be blown about by wind.

Impulse systems work by water pressure from ram or other pumps. Water is ejected in a stepwise circular pattern, nozzles rotating several degrees as each jet of water is released. The nozzles are designed to spray a radius of up to 15 m or a diameter of 30 m. Since water is shot into the air, it falls back as large droplets similar to rainfall. This irrigation system is the simplest type. It is readily purchased as a portable system that is hooked into a main water line (>7.6 cm in diameter) within a few minutes.

Impulse systems are most efficient for bare-root beds in which water easily diffuses throughout the soil, a more difficult process when seedlings are in containers. Containerized nurseries in Hawaii and in the Blakawatra nursery in Surinam have successfully used impulse sprinkler systems. However, nurseries in both countries used rigid-walled containers. Nonrigid bag tops, e.g., plastic bags, tend to collapse, impeding water from entering soil in the bags.

Basic knowledge of water pressure and flow are desirable when nursery managers do not have access to a hydrologist or pump technician. The data below were calculated from formulas in a basic text on hydraulics (*1*). Average atmospheric pressure is assumed to be 1,033 g/cm^2, and the specific weight of water is 304.8 kg/m^2 (at 21°C). If a barometer were constructed using water, the water column at normal atmospheric pressure would rise to 10.3 m; with a slight correction, because of vapor pressure, height of the column would actually be 10.1 m.

By association, a water column that is 0.7 m high exerts a pressure (i.e., has a hydraulic "head") of 70 g/cm^2. Estimates of water pressure can then be made for storage tanks of known heights by using this relationship:

$$\frac{P_1}{H_1} = \frac{P_2}{H_2}$$

where P_1 = standard atmospheric pressure (1,033 g/cm^2),
P_2 = potential pressure (g/cm^2) exerted by water in any storage tank,
H_1 = height of water column (m) at standard atmospheric pressure,
and H_2 = height of water (m) in storage tank.

For example, if a water tank is 30.5 m above a nursery area, the potential pressure for any irrigation system is:

$$\frac{1{,}033\ g/cm^2}{10.1\ m} = \frac{P_2\ g/cm^2}{30.5\ m}$$ and, by rearranging and simplifying,

$$(102.3) \times (H_2) = P_2 \text{ or}$$

$$(102.3) \times (30.5) = 3{,}120\ g/cm^2\ .$$

Similarly, other reference examples are:

Head or height of water supply (m)	*Pressure (g/cm^2)*
0.3	30
3.0	310
4.6	470
15.2	1,550
22.9	2,340
30.5	3,120

II. General Management Scheme for Watering Nursery Seedlings

The following guides should help in determining orrect application of water for nursery seedlings. The uides are generally applicable to containerized and are-root stock in traditional or mechanized systems.

TRANSPLANT STAGE TO 3 WEEKS LATER

1. When necessary, lift several seedlings to check oot growth. Check the soil daily for moisture needs uring the first 2 weeks. Do not check the surface lone but rather the zone between 2 and 10 cm below he surface; this is the root zone that needs water.

2. If shade is used for 2 weeks following transplantng, adjust watering to actual soil conditions and eeds.

3. The first 3 weeks is critical for watering because xcess soil moisture causes damping-off. *Never* add ertilizer in a water soluble form during this stage.

3 WEEKS TO 2 MONTHS

1. Cut back on watering frequency. If very sandy oil is used in containers, do not under-water.

2. Watch for hypocotyl and stem growth change to voody tissue. When this physiological change occurs, vater soluble fertilizers can be applied.

3. Maintain soil surface somewhat drier to avoid noss build up.

4. If not added before sowing, add mycorrhizal ungi to watering can and sprinkle seedlings during he fourth, fifth, and sixth weeks.

5. Inspect bottoms of bags; do not let water accumulate there.

6. Inspect sides of bags. If roots are concentrated in uter space between soil and bag, poor aeration is ndicated. Reduce shade, if any, and cut back on vatering.

2 TO 4 MONTHS

1. Use water soluble fertilizers at highest rates posible that do not cause excessive branching and excesive greening.

2. When adding fertilizers to irrigation water, do so t the end of watering periods to prevent fertilizer from washing out of containers, but rinse foliage with unfertilized water before ending the irrigation cycle.

3. Water as often as necessary to maintain a vigorous, succulent flush.

4. Avoid water stresses that can make seedlings semi-dormant in this stage.

5. Avoid heavy use of chlorinated or high-salt-content water.

6. When possible, use a soil moisture tester (tensiometer) to determine water tension in the soil. Probes are placed in the root zone area, with at least three readings per bed, each taken at a different position.

7. If a soil solu-bridge tester is used to take conductivity readings, more accurate readings are obtained *before fertilization* rather than afterwards. Soluble salts released by fertilizers tend to increase conductivity between the electrodes, causing a bias. Also, use a probe having the smallest possible diameter to avoid physical damage to the roots. Do not excessively wiggle the probe; this allows poor contact with the surrounding soil.

4 TO 7 MONTHS

1. Pine seedlings and most other subtropical species are ready for outplanting 5 to 7 months after germination. Thus, if hardening-off of seedlings is required, now is the time to do so.

2. Hardening-off is not entirely possible with semi-dormant pines. As a minimum, one tries to reduce succulent tissue growth by gradually decreasing watering frequency.

3. Bagged *P. caribaea* seedlings in clay loam soil normally survive 24 days or longer without water. However, serious damage occurs to seedlings grown in small volume containers filled with peat-based mixtures if more than 8 days go by without water. Death often occurs within 16 days if there is no watering. The best guide for nursery managers is experimentation with size of seedlings desired, preferred container type, and potting medium used. Because climatic conditions are different for each country, only experience and experimentation will indicate which water regime is best for a given species/container/pot mix combination.

III. Injector Alternatives for Soluble-Nutrient Watering Systems

Several types of liquid fertilizer injectors are available. The basic components of a precisely controlled injection system are:

- storage tank with an internal agitator to keep the solution thoroughly mixed;
- filter on the outer valve of the storage tank;
- pump that controls rate of injection into water lines, and
- pressure relief valve for the storage tank inlet and outlet valves.

Because of the corrosive nature of fertilizers, always use tanks, water lines, and pumps made of corrosion-resistant materials. Some leeway exists about the type of design needed to ensure adequate fertilization through nutrient injectors. Snedigar (*2*) presented the design for a simplified nutrient injector. It operates by air pressure within storage tanks, not by water-operated or motor-driven pumps. A skilled machinist can construct a similar injection system if he has blue prints or a diagram of the system used. Generally, for commercially bought units, the more expensive units give more precise injection rates.

Nutrient injectors are also activated by flowmeters. In one design, a watermeter installed in the wa pipe counts the flow of water in liters. A solenoid top of the water pump receives an electronic sig from the watermeter, which indicates water flow the irrigation line. The solenoid valve then opens a feeds an exact proportion of fertilizer into the wa line to make up the required dilution.

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PESTICIDE PRECAUTIONARY STATEMENT

Pesticides used improperly can be injurious to man, animals, and plants. Follow the directions and heed all precautions on the labels.

Store pesticides in original containers under lock and key—out of the reach of children and animals—and away from food and feed.

Apply pesticides so that they do not endanger humans, livestock, crops, beneficial insects, fish, and wildlife. Do not apply pesticides when there is danger of drift, when honey bees or other pollinating insects are visiting plants, or in ways that may contaminate water or leave illegal residues.

Avoid prolonged inhalation of pesticide sprays or dusts; wear protective clothing and equipment if specified on the container.

If your hands become contaminated with a pesticide, do not eat or drink until you have washed. In case a pesticide is swallowed or gets in the eyes, follow the first-aid treatment given on the label and get prompt medical attention. If a pesticide is spilled on your skin or clothing, remove clothing immediately and wash skin thoroughly.

Do not clean spray equipment or dump excess spray material near ponds, streams, or wells. Because it is difficult to remove all traces of herbicides from equipment, do not use the same equipment for insecticides or fungicides that you use for herbicides.

Dispose of empty pesticide containers promptly. Have them buried at a sanitary land-fill dump, or crush and bury them in a level, isolated place.

Use of trade, firm, or corporation names is for the reader's information and convenience. Such use does not constitute official endorsement or approval by the U.S. Department of Agriculture of any product or service to the exclusion of others that may be suitable.

Liegel, Leon H.; Venator, Charles R. A technical guide for forest nursery management in the Caribbean and Latin America. Gen. Tech. Rep. SO-67. New Orleans, LA: U.S. Department of Agriculture, Forest Service, Southern Forest Experiment Station; 1987. 156 p.

Presents a comprehensive summary of forest nursery practices for the Caribbean, tropical Latin America, and, to a lesser degree, other tropical areas in the world. Actual and recommended practices are discussed, and the advantages and disadvantages of each are given with specific examples wherever possible. Included are chapters covering overall nursery planning, general seed management, and small- and large-scale nursery operations.

Additional keywords: Seedbed preparation and sowing, container and bare-root systems, pest and disease control, nursery nutrition.

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Ecological, Physical, and Socioeconomic Relationships Within Southern National Forests

Proceedings of the Southern Evaluation Project Workshop

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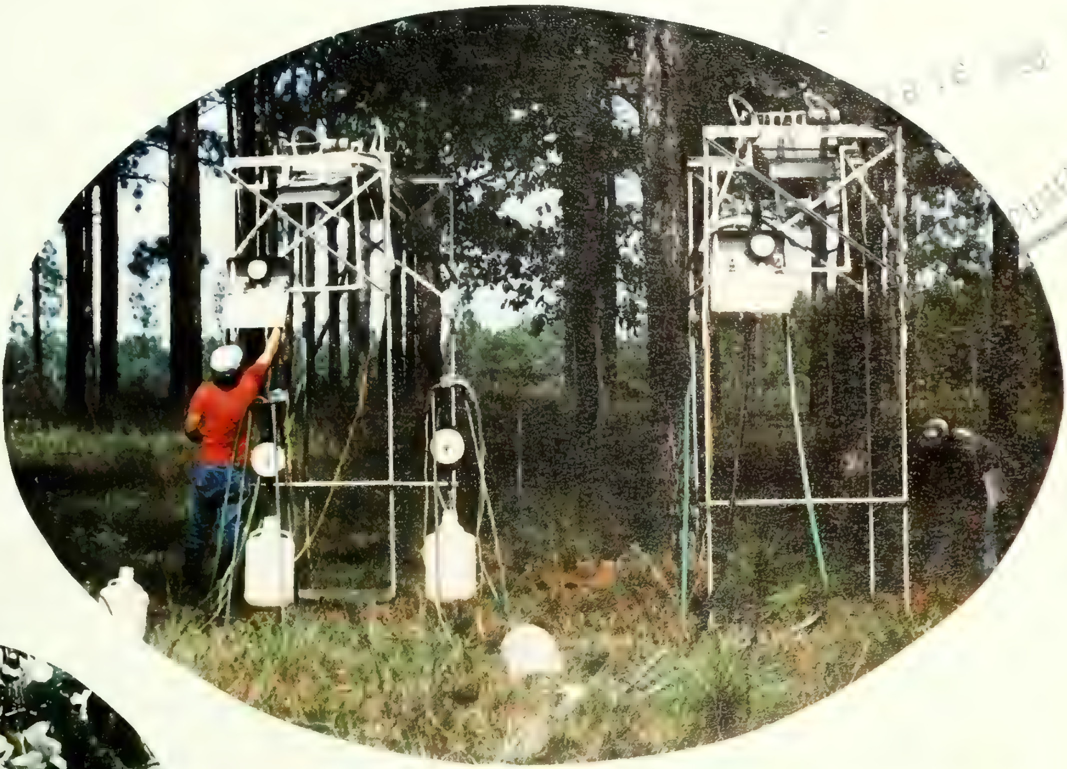

U.S. Man and the Biosphere Program

October 1987

Ecological, Physical, and Socioeconomic Relationships Within Southern National Forests

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PREFACE

There are about 182 million acres of forest land in the southeastern United States that provide grea potential for multiple use. These lands are intermixed in federal (10%), forest industry (23%), and othe private (67%) ownerships. More than 60 million acres are covered by pine types, mainly loblolly-shortlea pine but also a large amount of longleaf-slash pine.

The National Forests comprise most of the federally owned land in the Southeast. The forest resourc are diverse and intertwined but are integrated into a multiple-use forest management program. Wildlife indicator species are given in Forest Management Plans; these plans establish and describe management direction and monitoring and evaluation requirements needed to ensure compliance.

Since multiple-use or multi-purpose forest management has been practiced and discussed, both practitioners and researchers have asked about interactions between timber, range, wildlife, and other forest management practices. In 1978, forest managers and researchers had their first opportunity to examine these interrelationships by major pine types over a broad area when the Southern Evaluation Project was approved. Five areas, were delineated for study in the longleaf-slash pine and loblolly-shortleaf pine-hardwood types of the National Forests in four southeastern states (Texas, Louisiana, Mississippi, and Florida). Soil, watershed, vegetation, wildlife, and socioeconomic aspects were measured on the areas to provide a data base regarding current management, soil, vegetation, and wildlife diversity.

On May 26-27, 1987, a workshop was held in Long Beach, Mississippi, to discuss results obtained fro the Project. The workshop served as a forum in which researchers, resource specialists, managers, and administrators discussed management and ecological relationships on the Southern Region's National Forest The results of 43 research projects were presented and discussed. The workshop presentations, discussion following the presentations, an executive summary, and appendixes with lists of attendees and of prior publications, presentations, and reports generated from this project are published in these proceedings.

The project and workshop were primarily sponsored and supported by the USDA Forest Service, but also supported by the USDA Soil Conservation Service, USDI Fish and Wildlife Service, several universities, an the Southeastern Association of Fish and Wildlife Agencies. University support was provided from Texas A M University, Stephen F. Austin State University (Texas), Louisiana State University, Northwestern State University (Louisiana), Mississippi State University, University of Florida, Virginia Polytechnic Institu and State University, Utah State University, and Colorado State University. The project was endorsed by the U. S. Man and the Biosphere Program (MAB-3) on grazing lands, which was developed through the Unite Nations Education, Scientific, and Cultural Organization (UNESCO) and is sponsored by the U. S. Departmen of State.

Special thanks are extended to the contributors who prepared and presented papers, to the six moderators (Kent T. Adair, Stephen F. Austin State University, Nacogdoches, TX; Thomas H. Ellis, Southern Fores Experiment Station, New Orleans, LA; Douglas P. Richards, Mississippi State University, Mississippi State, MS; Robert T. Jacobs, Florida National Forest, Tallahassee, FL; Robert C. Joslin, Kisatchie National Forest, Pineville, LA; Dan W. Speake, Fish and Wildlife Service, Auburn, AL) who guided the sessions and follow-up discussion, and to the two wrap-up convenors (Robert G. Merrifield, Texas A & M University, College Station, TX, and Clifford E. Lewis, Southeastern Forest Experiment Station, Gainesville, FL) who synthesized and summarized general impressions and pertinent points from the entire workshop plus leadin in the final discussion. The Gulf Park Campus, University of Southern Mississippi, Long Beach, Mississippi, and local arrangements by Mary Tullos and Henry D'Aquilla were excellent and greatly appreciated. The Workshop Steering Committee consisted of Bruce L. Baldwin (Southern Region, USDA Forest Service, Atlanta, GA), Fred E. Smeins (Texas A & M University, College Station, TX), and Henry A. Pearso (Southern Forest Experiment Station, USDA Forest Service, Pineville, LA).

Papers published in this proceedings are as they were submitted by the authors--in camera-ready form. Authors are responsible for the content and accuracy of their papers. Printing and production were supervised by the Information and Publication Services staff of the Southern Forest Experiment Station, USDA Forest Service, New Orleans, Louisiana. Mention of trade names or a proprietary product in this proceedings does not constitute endorsement by the USDA Forest Service or any other federal or state organiza tion.

Henry A. Pearson, Fred E. Smeins, and Ronald E. Thill

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The Southern Evaluation Project--An Executive Summary

Henry A. Pearson, Fred E. Smeins, and Ronald E. Thill

Abstract.--The results of 43 projects, which evaluated the flora, fauna, watersheds, socioeconomics, and forest pests located on southern National Forests were presented and discussed in 4 major categories: Management Outlook and Evaluation, Loblolly-Shortleaf Pine Type, Longleaf-Slash Pine Type, and Watersheds, Socioeconomics, and Forest Pests.

National Forests, as well as private forests, aross the South will experience greater demands fr their resources in the future. Greater emphass will be placed on integrated resource managemnt with increased attention toward maintenance of botic diversity and multipurpose management. This wll require increased interaction between various rsource managers and scientists as well as greater atention to the needs and desires of the various frest users.

Broader-based ecosystem management approaches c the National Forests are an indication of this tend. National Forest Management Plans, that have rcently been developed or are near completion, are poposing improved mechanisms for multipurpose mnagement. The Forest Service is mandated by Cngress to produce and monitor timber, wildlife, rcreation, forage, and clean water on a sustained yeld basis.

The Forest-Range Environmental Study in the erly 1970's was designed to assemble information o the Nation's forests and rangelands. A result of is effort was creation of the Accelerated Range ogram. This program was designed to provide an tegrated, multiresource evaluation of our forest-nge ecosystems. Three locations were selected, cluding the Southern Evaluation Project area, to rve as test sites.

A collaborative effort of several federal, ate, and private groups across the South was iniated to evaluate the soil, water, flora, fauna, d socioeconomic parameters of National Forests Florida, Mississippi, Louisiana, and Texas. ly pretreatment measurements were accomplished cause funding was withdrawn prior to treatment plication. The loss of funds resulted from tional budget problems and priorities, rather an a lack of interest. Findings of initial tudies are summarized in this proceedings.

FLORA

Two major upland forest types were evaluated: the loblolly-shortleaf pine (*Pinus taeda-P. echinata*)-upland hardwood type (LSH) in Texas and Louisiana, and the longleaf-slash pine (*P. palustris-P. elliottii*) type (LS) in Louisiana, Mississippi and Florida (Figure 1). Primary objectives of the investigations were to (1) quantitatively characterize the overstory and understory vegetation, (2) relate overstory vegetation parameters to understory browse and herbage production, and (3) relate plant communities and production to soil types. Each study area occurred on National Forest lands and varied between 7,000 and 13,000 acres. All areas included considerable soil-topographic variation as well as variable past silvicultural, burning, and grazing impacts; plant communities were correspondingly variable. The LSH type in Texas and Louisiana was predominantly covered by sawtimber and pole size classes (97% in Texas, 80% in Louisiana). The LS type in Louisiana was 68% sawtimber, 9% pole, 14% seedling and sapling, and 9% regeneration. Most of the LS type in Mississippi was open-grown sawtimber and pole stands, while in Florida about 55% of the area was open-grown sawtimber and pole stands with 23% in titi (*Cyrilla racemiflora* and *Cliftonia monophylla*) and pondcypress (*Taxodium distichum*) swamps.

Upland soils across all study areas were generally sandy, acidic, and low in fertility. Landscape position, slope, drainage regime, depth of surface soil, and permeability of the subsoil are major features that influence vegetation composition, structure, and forage yield. Complexity of soils varied from 5 soil series identified in the LS type in Louisiana to 17 in the LS type in Florida. Most series were classified as Ultisols, with Alfisols the second most common soil order. Alfisols were more common in the western study areas (Texas, Louisiana); Spodosols were found only in the Florida study area. Vertisols were identified only for the Texas site where they covered one-third of

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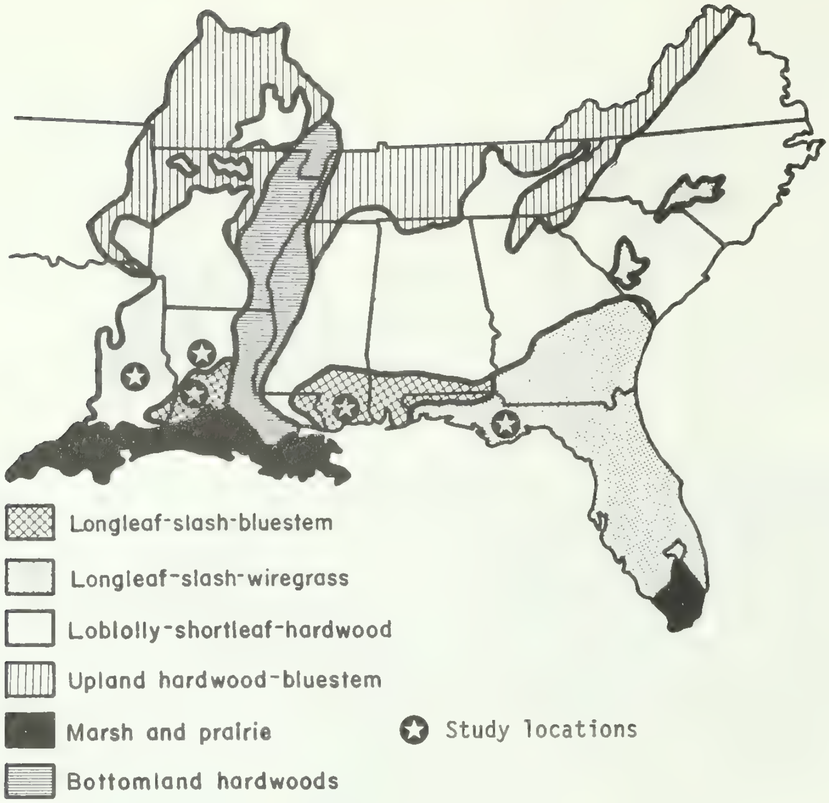

Figure 1.--Forest-range types of the South.

the area. Bottomland soils were primarily Inceptisols and Entisols.

Pine species contributed more than 70 percent of the canopy cover and basal area of most stands across all study areas. Most overstory dominants on all study areas were less than 60 years of age due to one or more timber harvests prior to or subsequent to their incorporation into the National Forest System. Hardwood dominated stands covered only small acreages of each study area, but hardwoods dominated the developing, successional understory and middlestory of most stands unless controlled by prescribed burning or silvicultural practices.

Plant species diversity tended to be fairly high across all study areas. Degree of soil-topographic variability and past disturbance greatly influenced the richness and composition of the communities. Most areas had a total of over 200 species, but up to 300 species were recorded on some areas.

Generally more than 50 woody species occurred with up to slightly more than 100 species in the Texas LSH type. Overstory species were characterized by the four major pine species (Pinus taeda, P. echinata, P. palustris and P. elliottii), several species of oaks (Quercus spp.) were the major and most diverse hardwood group on any given study site. Sweetgum (Liquidambar styraciflua), sweetbay (Magnolia virginiana), and blackgum (Nyssa sylvatica) were other commonly encountered hardwoods. Shrubs were diverse with greater than 40 species on most areas. Holly (Ilex spp.), especially yaupon (I. vomitoria), gallberry (I. glabra), and baygall holly (I. coriacea), were universally encountered. Blackberries (Rubus spp. blueberries (Vaccinium spp.), and waxmyrtle (Myric cerifera) were widespread. Nine (9) to 24 species of vines were encountered, with greenbriers (Smila spp.), jessamine (Gelsemium sempervirens), grapes (Vitus spp.) and poison ivy (Toxicodendron radicans) being widespread.

Grasses and grasslikes contributed between 40 and 50 species. Significant grass genera across all areas were the bluestems (Andropogon spp. and Schizachyrium spp.), panicum grasses (Dicanthelium spp. and Panicum spp.), and threeawns (Aristida spp.). Pinehill bluestem (Schizachyrium scoparium was widespread and often abundant in the relativel open upland stands. Wiregrass (Aristida stricta) was the most ubiquitous grass on Florida longleaf-slash sites, while uniolas (Chasmanthium spp.) wer important in partially open to nearly closed-canopied LSH stands.

Forbs were the most diverse species group and varied from 90 to 150 species across the study areas. Legumes varied between 12 and 26 species. Tephrosias (Tephrosia spp.), pencilflowers (Stylosanthes biflora) and tickclovers (Desmodium spp.) were the most ubiquitous genera. The biomas of legumes was relatively low on all areas but mor on the LS type as compared to the LSH type. posites were generally the most diverse group of bs with 50 or more species recorded for each a. Composite genera with several species luded Aster, Solidago, Liatris, and Eupatorium. most widely distributed and abundant fern was cken fern (Pteridium aquilinum).

Herbage and browse yield varied by stand type, nd size class, and in relation to yearly preci- ation variation. Herbage yield ranged from less n 100 lb/acre for closed-canopied stands to as h as 2500 for open pine savannahs, while browse ied from approximately 100 to 300 lb/acre. An erse relationship existed between herbage and wse yield and overstory features such as canopy er and basal area. Since most areas consisted closed to nearly closed-canopied forest, forage lds were generally low across all study areas. cipitation across all study areas exceeded the rage by 15 to 27 inches in 1979. In 1980 the as site received 10 inches less than average cipitation while Florida received 7 inches less the other areas were near their averages. sequently, understory yields were reduced from 9 to 1980--particularly in Texas and Florida. s was especially evident for the vine, forb, ss, and fern categories. In their current te, most areas have limited carrying capacity livestock or deer.

FAUNA

Pretreatment baseline wildlife data were llected on each of the five SEP study areas. imal groups sampled on all areas included birds, all mammals, and herpetofauna (amphibians and ptiles). Sampling efforts were concentrated on ese vertebrate groups, but relative abundance of d- and large-size mammals was also estimated at veral sites. Fish populations were sampled only the Mississippi study area.

As initially planned, each investigator was to mple seedling (regeneration sites), sapling, le, and sawtimber stands and comparisons across and size classes and vegetation types (LSH and) were to be derived. On four of the study areas vestigators were able to locate at least some reage in each of these four forest stand size asses. Representative younger stands were not ailable on the Florida site. There, the investi- tors compared wildlife abundance and diversity in tural longleaf pine stands with that found in anted slash pine stands. Unfortunately, there s virtually no standardization of techniques or mpling designs among investigators. Sampling asons, duration, and intensity also varied among eas. Results were also confounded by such fac- rs as differences in extent and recency of escribed burning and unplanned presence of ttle. To further complicate matters, rainfall bstantially exceeded long-term averages on all tes in 1979, but was well below average on the orida and Texas sites in 1980 and again in orida in 1981. Drought conditions dramatically duced some small mammal and bird populations, and ad and frog vocalizations were depressed. nsequently, few specific comparisons or generali- ations can be derived across study areas or forest types. Despite differences in methodology, it should be indicated that sampling procedures that were employed would have been adequate (in most cases) to detect within-site treatment effects on some wildlife species had the treatments been imposed and monitored. In the following brief summaries, we have only attempted to make some very general observations regarding relative abundance (and in some cases species diversity) for each animal group. Comparisons of the Florida data with other sites are not included below because they were not obtained for comparable stand size classes. However, birds, herpetofauna, and small mammals generally favored longleaf pine habitats over slash pine habitats, which, in light of the substantive diminishment (>80%) of longleaf pine in Florida during the past 3 decades, raises concern for the future of these vertebrate groups in the pinelands of north Florida.

HERPETOFAUNA

Loblolly-Shortleaf Pine Sites

Amphibian populations and number of species were more closely tied to availability of streams and ponds than to differences in stand size classes. Sawtimber stands in Louisiana contained more water sources than other stands and amphibians were more abundant. Water was more available in seedling stands in Texas and species richness and abundance were greater there than in other stand size classes. A total of 11 amphibian taxa were encountered in Louisiana compared with 15 for Texas.

Reptiles are generally less dependent on water availability and appeared to be more related to differences in stand size classes. Twenty-three (23) taxa were encountered in Texas and 20 in Louisiana. Green anoles (Anolis carolinensis), northern fence lizards (Sceloporus undulatus), and ground skinks (Scincella lateralis) were relatively abundant at both locations. Green anoles and ground skinks showed similar patterns of abundance at both sites, being most abundant in sawtimber and least abundant in seedling areas. In Louisiana, northern fence lizards were most abundant in sawtimber and least abundant on seedling sites. In Texas, the reverse was true, with none found in sawtimber.

Longleaf-Slash Pine Sites

Thirteen (13) amphibian taxa were encountered on Louisiana sites compared with 17 (excluding bayheads) in Mississippi. Twenty-one (21) reptiles were encountered in Louisiana compared with 36 in Mississippi. Higher taxa numbers in Mississippi were likely related to greater sampling efforts and a greater diversity of censusing methods. Mississippi sites also had an abundance of wet bayheads that served as population reservoirs for many herpetofauna. In Mississippi, species diversity was similar among stand size classes, varying from 33 herpetofauna taxa in seedling to 38 in sapling stands.

SMALL MAMMALS

Loblolly-Shortleaf Pine Sites

Fulvous harvest mice (*Reithrodontomys fulvescens*), cotton mice (*Peromyscus gossypinus*), and golden mice (*P. nuttalli*) were abundant small mammals at both LSH sites. Additionally, rice rats (*Oryzomys palustris*), hispid cotton rats (*Sigmodon hispidus*), and eastern woodrats (*Neotoma floridana*) were abundant on the Texas site, while shorttail shrews (*Blarina brevicauda*) and white-footed mice (*P. leucopus*) were common in Louisiana. Total catches of small mammals were highest in early successional stages at both sites. Methods employed for monitoring large and mid-size mammals were generally unsatisfactory at both locations. Track counts yielded the most data for deer in Louisiana relative to night spotlight surveys and scent stations.

Longleaf-Slash Pine Sites

Species richness of small mammals was similar at both longleaf-slash pine sites despite differences in methods and sampling effort. Trapping with Sherman live traps and snap traps yielded about seven taxa over all stand size classes at both locations. Shrews (*Cryptotis* spp. and *Blarina* spp.) and mice (primarily *Peromyscus gossypinus* in Mississippi along with *P. leucopus* in Louisiana) were the most abundant small mammals trapped at both sites. In Louisiana, shrews were caught more successfully in drift fence-pitfall traps than in Sherman live traps and snap traps. Total numbers of small mammals tended to be higher in older stands, but differences were more related to microhabitat differences than timber size classes.

BIRDS

Loblolly-Shortleaf Pine Sites

The number of bird species encountered was comparable for both the sites, with 106 recorded in Louisiana and 115 in Texas. Principal spring birds on the Texas site included northern cardinals (*Cardinalis cardinalis*), red-eyed vireos (*Vireo olivaceus*), pine warblers (*Dendroica pinus*), Carolina chickadees (*Parus carolinensis*), tufted titmice (*Parus bicolor*), yellow-breasted chats (*Icteria virens*), and Carolina wrens (*Thryothorus ludovicianus*). The most common species in Louisiana included northern cardinals, blue jays (*Cyanocitta cristata*), Carolina wrens, white-eyed vireos (*Vireo griseus*), and tufted titmice. Drought conditions in Texas caused slight declines in numbers of species and drastic reductions in numbers of individuals during winter, especially within seedling and sapling stands.

Longleaf-Slash Pine Sites

Avian species richness was comparable on both LS sites during summer, with 54 species encountered in Louisiana and 55 in Mississippi. The most common summer birds on the Mississippi site were American crows (*Corvus brachyrhychos*), blue jays, northern cardinals, and rufous-sided towhees (*Pipilo erythrophthalmus*). Highest summer densities in Louisiana were recorded for blue jays northern cardinals, brown-headed nuthatches (*Si pusilla*), pine warblers, and Bachman's sparrow (*Aimophila aestivalis*). Bachman's sparrow, a s cies thought to be rare, had the highest averag density of any of the Louisiana summer birds. Mississippi, eastern wood pewees (*Contopus vire* and Kentucky warblers (*Oporornis formosus*) were both relatively common; both had been thought t rare in that part of the state. At least one pa each of Louisiana waterthrushes (*Seiurus motacil* and Swainson's warblers (*Limnothlypis swansonii*) were thought to have nested on the Mississippi site. Prior to this study, neither were known t nest so far south in the state. Differences in bird abundance and diversity were generally prec table based on differences in habitat diversity structural complexity.

FISH

Longleaf-Slash Pine Sites

In October 1981, two days of electrofishing (along with a limited seining effort) on streams within the Mississippi study site yielded 26 fis species which represented 11 families and 16 gen Streams sampled differed widely in water and sub strate characteristics and fish composition vari accordingly in a predictable fashion. Minnows o shiners (*Notropis* spp.), chubsuckers (*Erimyzon* spp.), madtoms (*Noturus* spp.), darters (*Etheosto* spp. and *Percina* spp.) and topminnows (*Fundulus* spp.) were considered to be good indicators of habitat changes. Many of these fish have been identified as indicator species in National Fore Management Plans.

WATERSHEDS, SOCIOECONOMICS, AND PESTS

Influences of regeneration/harvest method, preparation, and cattle grazing on storm flow an sediment loss were evaluated on five small exper mental watersheds on the Texas LSH study area. While harvest method and mechanical site preparation all increased storm flow, peak discharge rates, and sediment loss compared with undisturb watershed, they were not of an order of magnitud that was considered detrimental to long-term sit stability. Grazing was only evaluated for one y but results suggested that grazing impacts were negligible at proper stocking rates.

On the Louisiana LS site, silvicultural and grazing combinations were evaluated for their influences on infiltration and runoff water quali Results indicated that these practices had minima impacts on the soil and water resources. Infiltration rates and sediment production from longterm burning plots in the Louisiana LS type were not greatly affected compared to unburned controls. Timing of burning to coincide with periods of rapid vegetation regrowth (late sprin minimizes burning impacts. When considered in relation to the positive benefits of fire as a vegetation management tool, its influences on soil and water parameters would fall within acceptable limits.

Grazing by livestock has been practiced on the uthern forests since the late 1700's and has con- nued as a major agricultural enterprise. A pre- minary evaluation of contemporary forest grazing d associated sociological and demographic pheno- na was conducted on the Mississippi LS study area ere livestock grazing is widely practiced. wever, conflicts with ever-increasing demands for ner uses and a growing rural population makes tential for conflict great. Greater management puts and educational programs will be required to low multiple uses, including grazing, to co-exist the forests.

Economic analyses for beef cattle production conjunction with pulp and sawtimber rotations on e the southern forest suggest that the potential exists for much greater production with a concomitant increase in total welfare. Individual producers might, however, expect a real decrease in net returns for their products.

The interaction of grazing with tree pests (insects and diseases) has not been adequately evaluated, nor have these interactions been related to other forest management practices. Surveys indicated that root rot fungus (*Heterobasidion annosum*) was the most widespread potential disease problem related to grazing. While livestock can potentially be expected to create some problems, in terms of increasing the spread and abundance of some diseases and insects, careful management of stocking rates and timing of grazing would be expected to minimize these impacts.

MANAGEMENT OUTLOOK and EVALUATION

Moderator:

Thomas H. Ellis
Southern Forest Experiment Station
New Orleans, Louisiana

Synopsis Discussion Leaders:

Robert G. Merrifield
Texas A & M University
College Station, Texas

and

Clifford E. Lewis
Southeastern Forest Experiment Station
Gainesville, Florida

Forest land in the South exceeds 180 million acres extending from Virginia into eastern Oklahoma and Texas. About 18 million acres of these lands are owned by the public, while about 164 million acres belong to farmers, forest industry, and other private owners. The 12.5 million acres of National Forest in the South are managed to sustain yields of high quality forest resources, while protecting the environment and providing for other desired uses of the forests. Federal budgets are declining and the work force shrinking; consequently, management efficiency must increase.

National Outlook for National Forest System Lands and Resource Management in the Southeast

Robert M. Williamson

I am very pleased to be here with you today presenting the Chief of the USDA Forest Service, le Robertson. Dale sends his regrets at not ing here in person. I am going to preface my marks with some now all too familiar statements at you hear every day when the future of the rest Service is discussed. In today's economic imate it is highly unlikely that there will be y increase in budget or manpower in the foreeable future. Our budgets are in fact declining d our work force shrinking. This means we have increase our efficiency in management of the tional Forests.

National Forest lands are the largest blocks public land dedicated to multiple use purposes the South. Most private forest lands are comtted to single purpose development with some conderation given to other uses if they can be made produce a monetary return. National Forest nds on the other hand, are multi-purpose lands ich meet diverse public needs. As such they have lue to the public quite different from the private nds that surround them. The opportunities are eat to satisfy both commodity and non-commodity es. Some of these opportunities have already en discussed today by the various speakers, and am sure, will be discussed further tomorrow.

Demand for timber, wildlife and fish, and nerals from the National Forests is increasing. w demand for livestock grazing combined with creased demand for wildlife, dispersed recreation d wilderness continue to be issues in the South.

We will continue to emphasize multiple use nefits of timber, range, recreation, water, ldlife, and wilderness where designed by Congress the National Forests in an effort to demonstrate e economic and resource management opportunities at can be applied on forested lands under multiple e management. The economics of timber production Southern National Forests is good, but the ecomics of timber production, livestock grazing and ldlife production in combination can be even eater if carefully planned and managed. If it is ne with sensitivity and creativity, we can proide for special habitat needs of threatened and dangered species, produce quality water flows and intain a high level of quality recreation.

We are committed to balance in dealing with mmodity and non-commodity production of National rest resources. National Forest represent this mmitment. In every Forest Plan we have attempted achieve this balance in defining a preferred alternative based on public issues and management concerns, the needs of the local communities dependent upon National Forest System land, and our mission of "caring for the land and serving the people." In a large number of cases (a number larger than I would like), the public has disagreed with us. We recognize that this nation has changed greatly since 1905, the founding of the Forest Service, and we are changing just as the South is changing to meet new problems and opportunities in this changing world of ours.

But as great as the opportunities are, it is a complex business. Careful planning must occur. In every Forest Plan, modifications and revisions have been extensive as a result of public input over what was proposed as a preferred alternative in the draft plan. Virtually all changes made were in the direction of more fully accommodating non-commodity user needs and modifying the amount, kind or timing of commodity production, mainly timber.

The public want the National Forests of the South to be something more than three farms, but still be responsive to public demand for wood products and other market items.

The recently completed Southern Timber Supply Study shows an increasing demand for a shrinking supply of wood from all ownerships by the year 2000 in the South. The National Forests will continue to supply a fair share of the wood needed to meet the demand in the future, but that fair share will be determined through our multiple use program. The Southern Timber Supply Study serves to emphasize the importance of the small residual islands of National Forest System lands relative to other ownerships as multiple use enclaves where wildlife and fish, including non-game, recreation and water quality share equal importance with timber production.

The integrated multiple use management prescriptions in our Forest Plans have identified a desired future condition of the vegetation. Our management is being designed to make those changes in the vegetation that are necessary to achieve multiple use goals. Those goals include both game and non-game wildlife and fish, threatened and endangered species, quality water and our traditional commodities of timber, forage for livestock production, and minerals. Admittedly this is a tall order. There are numerous examples throughout the South where we didn't get the prescription quite right. But then, too, there are many success stories.

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obert M. Williamson, Director, Range Management Staff, USDA Forest Service, Washington, D.C. 20250.

Throughout the South we have numerous examples of multiple use prescription which accommodate or even emphasize wildlife. The classic example is the red cockaded woodpecker, where rotation age and timing of harvest has been altered to accommodate the special habitat needs of this species. Notice I said rotation age and timing of harvest. Wood will still be produced. We must demonstrate that we can integrate and jointly achieve our goals.

Even more compelling is the use of prescribed fire to modify habitats for wildlife and produce forage for livestock and reduce forest pests without modifying rotation age or the basic timber production. We are turning demands for consumptive uses into tools to achieve resource objectives. As an example, livestock are used as a tool to maintain clearings in the forest to benefit wildlife and provide for ecological diversity. Tomorrow at one of the sessions, we will be discussing more of these kinds of opportunities.

The Southeast is climatically well suited for agroforestry. Some examples of success stories are the establishments of walnut plantations with tree spacings to accommodate mechanized equipment--fertilizer application equipment and hay processing equipment. Plantations are producing a quality forage resource (hay) and the walnut trees are benefiting from the fertilizer applied to produce a forage crop. As trees reach the size that tree spacing will not accommodate hay processing equipment, livestock grazing is introduced to consume excess forage. Have we looked at the opportunities for PECAN/HAY/GRAZING system in the South. Another example is where we are breaking down large expanses of cool season grasses (Kentucky Tall Fescue) and establishing native warm season prairie species for the benefit of wildlife, especially quail and small mammals (rabbits). Livestock grazing and haying are the tools of management used to maintain the native bluestems in a vegetation condition to maximize quail habitat.

Private industry is beginning to evaluate some of the practices in use on the National Forests and using these and similar techniques to improve game habitat. This improved habitat can be leased at higher fees for hunting than nonmodified or unimproved habitat. In many cases the benefits are complementary providing both increased lease revenues and increased timber revenues. I recently read where Robert O. Anderson, who at one time was the world's largest landowner, is systematical converting some of his ranchers over to primary wildlife production and is marketing the hunting rights.

This is not to say that we know it all. There is still much to be learned, tried and put to use in the management of both the National Forests and private forest lands. We have improved our management to integrate the many public needs and demands into our multiple use programs on the National Forests. Yet some of our data and information are less reliable than we would like. This is why I am particularly pleased that this Southern Evaluation Workshop is taking place at this time. We have taken our best shot at producing Forest Plans that meet our mission of caring for the land and serving the people. The findings of this workshop will help us evaluate what we have done, identify data gaps, missed opportunities, and yes, oversights and mistakes that might require correction and modifications to our plans. As these finding are identified, I challenge you to continue to think vegetation management and not just in terms of the traditional aspects of range, timber, wildlife, and water production. More importantly it will help us set priorities and focus research in areas of highest priority.

Just a little where we see livestock grazing in the Southeast. There may be more questions th answers. There never was a large demand for livestock grazing on the National Forests in the South. It is becoming more obvious that grazing the National Forest lands cannot be justified on the basis of "red meat" production only. First, there is a large acreage of marginal cropland available for grazing as crop acreage is reduced. These acres absorb most of the demand for livestoc grazing. Nine years from now as cropland begins t come out of the conservation reserve program, it is anyone's guess as to what will happen. Will CR be extended, will grazing begin to occur on these lands to provide a cash flow, or will they be plowed up and put into crops. I have seen some estimates that predict larger acreages of surplus cropland by the year 2000. This land cannot and will not stay idle. More private landowners are turning to "agro" forestry to improve cash flows.

Second, we are learning more about the use of livestock grazing as a means to meet vegetation management objectives. Thus, livestock on the National Forests will be considered more of a tool than a use. Livestock will be preferable in many areas to the use of herbicides in manipulating vegetation. In fact we may see the time when livestock cattle, sheep, or goats are paid to graz on NFS lands. It is occurring now.

Third, the basic grazing program on the National Forests in the Southeast will be to meet the needs of the small local livestock producers. These will be reduced over time. The peaks and th valleys in livestock numbers grazing on the National Forests will reflect the economic factors affecting the livestock industry as a whole in the United States, while demand by small producers and needs for livestock to manipulate vegetation will be the base program.

In summary, the management of National Forest in the Southeast will be one of:

1. More importance placed on rich and divers forest ecosystems on public lands. The shift to biotic diversity and multipurpose forest vegetation management will be a major criteria for good forestry on National Forest System lands. Silvicultural prescriptions will address a richer set of purposes.
2. Foresters, livestock managers, wildlife managers and others working as a team to increase their sense of partnership. The passwords are integration and leadership.
3. Shortages of the available supply of timber, recreation opportunities, and fish and wildlife, which will increase pressure for production of these resources.

National Forest System Management Perspectives: Timber, Livestock, Wildlife

Marvin C. Meier

Abstract--The Forest Service manages 12.5 million acres of forests in the Southern Region. These lands are managed to sustain a yield of high quality forest resources, while protecting the environment and providing for other desired uses of the forests.

Forest land management that incorporates cological principles has come of age! A good xample is the Southern Evaluation Project SEP). This forward-looking project provided he opportunity to research the interactions mong resources and apply findings. The need to anage the forest types studied, with an nderstanding of their ecological relationships, s increasingly more important.

ome examples:-

- the concern over clearcutting (diversity, isual soil and water implications).
- the increased interest in hardwoods, articularly mast-producing hardwoods, in oastal plain, piedmont and mountain forests.
- the wiregrass longleaf community.
- the titi/slash pine relationship.
- the increasing need for management and rotection of endangered, threatened and ensitive plant and animal species (red-cockaded oodpecker, gopher tortoise, roundleaf birch, arper's beauty, small whorled pogonia).
- increased concern over competition etween wildlife and livestock.

In the past, we have dealt mostly with opulations. Particularly, populations of ommercial timber species, i.e., loblolly, ongleaf, etc., or even deer in terms of umbers. We have begun to think more of plant ommunities, still with emphasis on a few embers of the community. This perspective is ppropriate. We need to move more and more to ommunity management. Use of habitat elationship models support this principle.

It is all right to focus on key species in he community as long as we realize two things. irst, that the models provide only an approxi-ation of impacts to the whole community; and econd, we must use an appropriate indicator pecies. This is an important aspect of the nowledge known beforehand or gathered in tudies such as those done for these projects.

We are thinking more toward ecosystem management. Why? Because we collectively (the Forest Service and the users) are demanding a variety, a broad spectrum, of outputs from communities and ecosystems (figs. 1 and 2).

In the long run, both we, internally, and the public, expect that the basic natural ecosystem will or should remain. We face no small task to extract figuratively and literally the "products" we want from an ecosystem, and still maintain ecological stability over time.

We still have our terminology--we manage timber. We manage range and wildlife. That concept is acceptable as long as we don't lose sight of the fact that each resource is only a part of the overall system.

We are not charged with "hands off" ecosystem management--just letting the natural cycles run. We are charged with managing forests to extract the "products" desired, while protecting long-run productivity. Our policies need to foster and carry out management concepts that would not destroy the natural aspect, but would provide a flow of products. We need, also, to say when a threshold is reached that precludes further production of a given product without undue damage to the natural system. The level at which this occurs is often based on our understanding of the total system and our ability to work within rather than outside natural processes. This is why the SEP was so important. For example, years ago we had not found a successful way to regenerate longleaf pine at an acceptable cost. So we planted slash pine on longleaf sites. When we cut longleaf on many sites we destroyed the longleaf community. The solution wasn't to stop extracting the longleaf products, but to find a feasible way to regenerate longleaf. Another example may be the red-cockaded

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emarks by Marvin C. Meier, Deputy Regional Forester for Resources Southern Region, USDA Forest ervice, 1720 Peachtree Road, NW, Atlanta, GA 30367

Figure 1.--A natural ecosystem is a closed system as far as our utilization of products is concerned, except for such things as migratory birds and water.

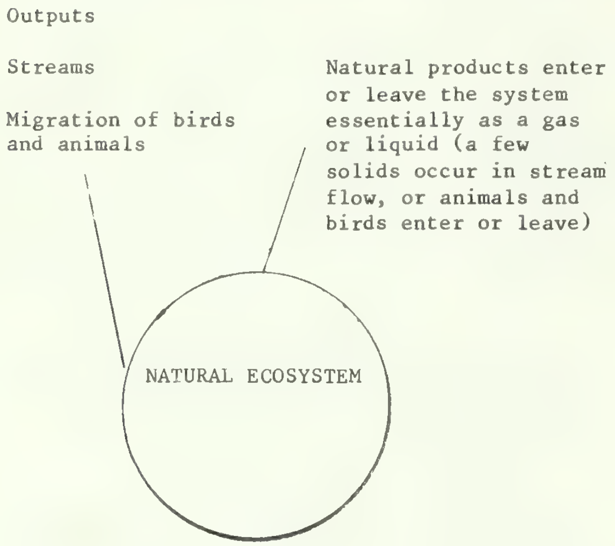
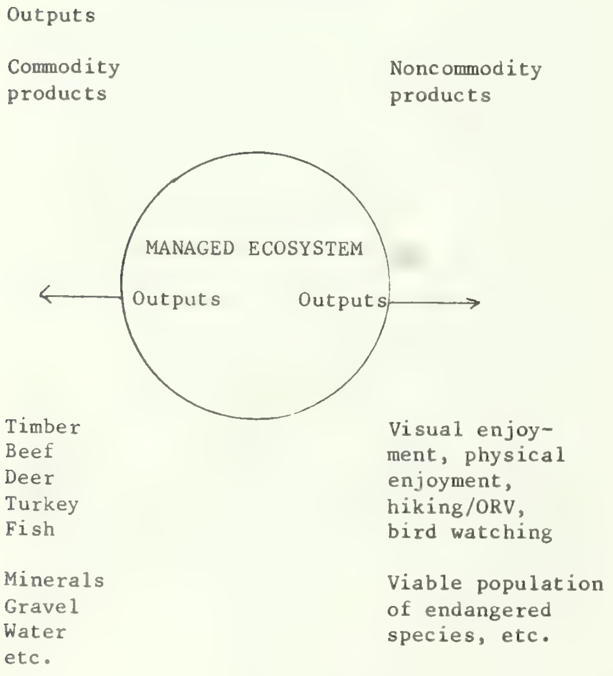

Outputs
Streams
Migration of birds and animals
Natural products enter or leave the system essentially as a gas or liquid (a few solids occur in stream flow, or animals and birds enter or leave)
NATURAL ECOSYSTEM

Figure 2.--We expect or demand a wide variety of outputs or "products" from a managed ecosystem.



woodpecker (RCW), as an endangered species. These birds require mature or old longleaf, loblolly or shortleaf. The solution is not to leave all these stands, but to find ways to extract the "products" we want, including the RCW, by modifying our methods. We have made some headway, but we have a ways to go.

A third example relates to extracting (maintaining) the visual resource while extracting timber or logs. We have moved toward clea cut shaping, shelterwoods--more seed tree cutti to maintain better visual resources. We have a opportunity to use uneven-aged management in some cases. Note, however, that changing practices affect other ecosystems' "products", potentially on the basic structure of the syste itself, so changes must be evaluated.

Consider the timber management/production and silvicultural systems in this Region. Criteria for prescribing appropriate silviculture systems are applied according to the management type under consideration. In th longleaf/slash and loblolly/shortleaf timber types, the even-aged system is more commonly used.

For each silvicultural system, there are two or more harvest (regeneration) cutting methods that may be used. The most appropriate harvest cutting method for a given timber stand depends on many factors. For example: species silvics, seed production, site characteristics, regeneration time, economics, availability of genetically-improved planting stock, aesthetic quality, other resource needs and requirements. The specific interactions of these factors must be considered on a case-by-case basis. The three harvest methods used in even-aged management are: clearcut, seed-tree and shelterwood.

Rotation in the even-aged management of southern pines will vary between species and ma vary within a management prescription for an analysis area.

Rotations are at least 180 years for longleaf and 70 years for other pines within compartments managed for RCW. Other alternatives are considered in the forest planning process and from informal consultation with the Fish and Wildlife Service.

As mentioned earlier, the principal concerns related to range in the Region are: economics of range grazing, range capability, the potential for resource damage, possible conflict with other resource uses and reducing grazing on National Forest System lands where such use is economically submarginal.

Some of the Coastal Plain forests (Texas, lorida, Mississippi and Louisiana) have been nvolved in the SEP project. Foresters there re trying some management practices that have rovided some valuable management information. uch of that data is mentioned in some of the ore technical presentations.

Significant aspects of the wildlife rogram, as mentioned, include: threatened and ndangered species, habitat improvement for big ame, small game, and non-game species and oordination with State agencies regarding game opulation management.

Active management (regeneration cuts, site reparation burning) of the longleaf/slash pine orests predominates in much of the southern oastal Plain from North Carolina to south-astern Texas. These management practices have een beneficial for several wildlife species, ncluding the RCW.

For example, the RCW increases in the longleaf type that has a history of burning, with little or no hardwood midstory. However, the RCW declines in the loblolly type in which hardwoods exist because of the lack of fire.

As stated earlier, our treatment of forests, specifically those studied by SEP, has evolved from total utilization of the timber--in some cases range--to timber and range emphasis coordinated with other needs and now toward more integrated management of all the various "products". The presently increasing demands for various products make it imperative that we use all the knowledge made available by SEP.

This conference promised to be very beneficial and important, by adding to our ecological knowledge. The information will certainly influence many of our management thoughts and practices. The personal contacts, presentations and a final proceedings are well worth the time spent.

A Basis for the Southern Evaluation Program

Gale L. Wolters and Ronald D. Lindmark

In the early 1970's a Forest Service study s designed to explore the current and potential oduction of resources and the role of grazing on l forest and range ecoystems--the forest-range-- thin the 48 contiguous United States. The pur- ose of the Forest-Range Environmental Study, tter known as the FRES study, was to assemble nformation about all of the Nation's range and to velop technology for its evaluation that would rve the planning needs of the Forest Service. eded was an orderly arrangement of management lternatives, each based upon an evaluation of nformation about the physical and biological sources of the environment. Social, political, nd economic needs were also to be considered.

It was concluded from the FRES study that razing of the Nation's forest-range environment as compatible with the increasing demands for ivestock feed, and that these increases could be chieved on a national basis, and without reduction n enviromental quality. Specifically, the FRES tudy reported that animal unit months of grazing ould increase 50 percent nationally and 147 per- ent on Eastern forest-range without reduction in nvironmental quality. As all of you may suspect-- nd as many of you will recall--there were many keptics of the study findings; many questioned he validity of the data. There were factions who wore *by* the study implications and other factions ho swore *at* the study implications within the orest Service as well as outside the agency.

In an attempt to resolve conflicts in opinion nd professional judgment the Chief of the Forest ervice, John R. McGuire and Staff agreed in 1973 o support an Accelerated Range Program. The rogram provided authorization for an interdisci- linary team of scientists to monitor and research he social, economic, biological, and ecological nterrelationships of forest-range resources to anagement strategies; to provide feedback for djusting program direction nationwide; and to emonstrate resource interrelationships on an perational scale. Because of the multiresource lavor, professionals from many scientific disci- lines contributed. Among the disciplines repre- ented were: forestry, range, ecology, watershed, ydrology, soils, wildlife and fisheries, econo- ics, recreation, landscape architecture, and com- uter science.

The Accelerated Range Program was a major gency effort. It included three regional research nd demonstration test sites and personnel from each of the nine Forest Service administrative regions, eight Forest and Range Experiment Stations, and two State and Private Forestry Areas. The National Forest System provided demonstration and study sites, financial support (which was a major contribution to the Southern Evaluation program), and technical expertise.

State and Private Forestry provided technical expertise, financial support and leadership for range improvements on private lands, interagency coordination, and technology transfer. Forest Service Research provided financial support, technical expertise and leadership for planning and implementation of the overall program, and facilitated technology transfer through various processes such as the current workshop.

The Accelerated Range Program was not totally a Forest Service program. Agricultural Research Service, Agricultural Stabilization and Conservation Service, and the Soil Conservation Service were valuable USDA cooperators. However, many industrial timber companies, state and private landowners, universities and research institutions also contributed substantially to the success of the Accelerated Range Program as you will hear more about during the next day and a half.

The three test sites selected for the Accelerated Range Program were: Eastern Oregon, Central Utah, and the Southern Coastal Plain. However, as a result of budget recession and changing agency objectives, plans for the three evaluation programs were restructured. For example, the Eastern Oregon program was completed in FY 1986 but the number of forest-range resources evaluated were scaled back from 18 to 6. The six remaining outputs were (1) herbage and browse, (2) water quantity, (3) water quality, (4) storm runoff, (5) economic cost--accounting, and (6) economic impacts. Likewise, the Central Utah program was trunkated to the point that it never preceded beyond an initial implementation stage. The Southern Evaluation Program, as we will hear about in detail the next couple of days, was initiated and substantial technology was developed.

Timber production in the South is and undoubtedly will remain the primary object of forest-range management. Historically the "burden of proof" for compatible multiple use management of Southern forest range was incumbent upon the non-timber resource advocates. Some technical information on southern forest range multiple resource

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ale L. Wolters, Forest Environment Research Staff, USDA Forest Service, Washington, D.C. 20090-6090 and
onald D. Lindmark, Director, Forest Environment Research Staff, USDA Forest Service, Washington, D.C.
0090-6090.

interrelationships and their compatible uses was available prior to the Southern Evaluation Program. However, the Southern Evaluation Program contributed substantially to filling gaps in our knowledge and enhancing our knowledge of natural resource relationships on Southern forest range. This new knowledge base will significantly facilitate land management planning and sound multiple resource decision making in the future.

I am excited to be here and have opportunity to hear specifically how this new technology will improve integrated resource management on our Southern forest ranges. I am also interested in learning how this knowledge will be used to direct our future research programs in the Forest Service.

The Southern Evaluation Project: Development and Results

Henry A. Pearson

Abstract.--The Southern Evaluation Project was a collaborative effort by several organizations to evaluate range, timber, wildlife, and watershed resources on National Forest System lands in the Southern United States. Sponsored by the USDA Forest Service, the project's goal was to promote sound, multiple-use management of the southern forested lands. The study was located in longleaf-slash pine (*Pinus palustris-P. elliottii*) and loblolly-shortleaf pine (*P. taeda-P. echinata*) forest types. Five study areas, each 8 to 12 thousand acres in size, were subdivided into four units to accommodate future range, timber, and wildlife management strategies. The subdivisions also provided replication of measured parameters. Soil, water, flora, fauna, and socioeconomic parameters were measured on the study areas. These measurements provided data for evaluating management, soil, vegetation, and wildlife diversity on the USDA Forest Service Southern Region's national forests. The project lasted for 5 years, and some watershed evaluations extended for 10 years.

INTRODUCTION

Population increases indictate a growing com-
tition in the future for the use of the land.
nd use practices will inevitably intensify as the
tion attempts to support population growth and
et the demands for food and fiber. Since
ltiple-use or multi-purpose forest management has
en practiced and discussed, both practitioners and
searchers are interested in the interactions
tween timber, range, wildlife, and other renewable
sources on southern pine forests. When the
uthern Evaluation Project was approved by the
ief of the USDA Forest Service in 1978, forest
nagers and researchers had their first oppor-
nity in the South for an indepth examination of
ese interrelationships by major pine types over
broad area.

The Resources Planning Act of 1974, the
sources Conservation Act of 1977, the National
rest Management Act of 1976, and the Multiple Use-
stained Yield Act of 1960 provided for the future
nagement, supply, and use of multiple forest and
nge land resources. The Southern Evaluation
oject was initiated to reinforce these Acts and
evaluate multiple-use interactions in the South.
e goal of the study was to promote sound
ltiple-use management of the southern forested
nds. In order to achieve this goal, three speci-
ic objectives were established:

1. To evaluate impacts of timber, wildlife, and range management alternatives from a biological, physical, economic, and social standpoint.

2. To provide appropriate technology transfer.

3. To demonstrate selected management strategies on an operational scale.

COOPERATION AND ORGANIZATION

The project was a joint effort of State and Private Forestry, Research, and the National Forest System of the U. S. Forest Service, with coordination from other agencies and organizations. Over 60 institutions, agencies, organizations and individuals provided input for the original project plan. Interested agencies and organizations were continually apprised of activities through appropriate designated contacts. The National Forest System was responsible for facility installation and maintenance as well as management. State and Private Forestry was responsible for technology transfer, and Research was responsible for measurement. Universities and organizations participating in measurements and/or technology transfer were: Texas A & M University, Stephen F. Austin State University, Louisiana State University, Northwestern State University (Louisiana), Mississippi State University, University of Florida, Virginia Polytechnic Institute and State University, USDA Soil Conservation Service, USDA Forest Service, USDA Agricultural Research Service, and Southern

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enry A. Pearson, Supervisory range scientist, Southern Forest Experiment Station, USDA Forest Service,
ineville, LA 71360.

Ecology Laboratory, Starkville, Mississippi. The project was endorsed by the U.S. Department of State's U.S. Man and the Biosphere Program Directorate on Grazing Lands (MAB-3).

BACKGROUND

In October 1980, a workshop was conducted in Lufkin, Texas, to explain past and present progress of the cooperative project and some of the anticipated results. More than 60 people from 3 State agencies, 9 universities, 4 Federal agencies and several special interest groups attended. Each received an abstract of the papers presented.

A report on the potential grazing systems to be used in the SEP was made at the 1981 annual meeting Society for Range Management, Tulsa, Oklahoma. Ideas were solicited from the 25 professionals who attended that session and were incorporated into project plans where possible.

The project has been discussed and interim reports made at several formal meetings including the 1980 Society for Range Management meeting in San Diego, California, the 1981 International Grassland Congress at Lexington, Kentucky, and the 1981 National Gopher Tortoise Council meeting in Jackson, Mississippi.

STUDY AREAS

The project was initiated on National Fores System lands in Texas, Louisiana, Mississippi, a Florida (figure 1). Two study areas located in Texas and Louisiana represent the loblolly-short pine (*Pinus taeda*-*P. echinata*) type; three study areas in Louisiana, Mississippi, and Florida provided the longleaf-slash pine (*P. palustris*-*P. elliottii*) type. The five areas were each 8 to thousand acres in size. All study areas were managed according to the USDA Forest Service Southern Region's guidelines for timber, range a wildlife. These guidelines are discussed in the proceedings by M. C. Meier, Deputy Regional Fore Southern Region, National Forest System. All are selected had a history of livestock grazing but w not necessarily being grazed when the study bega (table 1).

MEASUREMENTS

Scientists and managers from several univers ties and the Forest Service determined appropria sampling methods for general physical and biologi monitoring. Cooperative agreements between the Forest Service and cooperating scientists provide the appropriate expertises for evaluating physica and biological responses. Standardized measureme

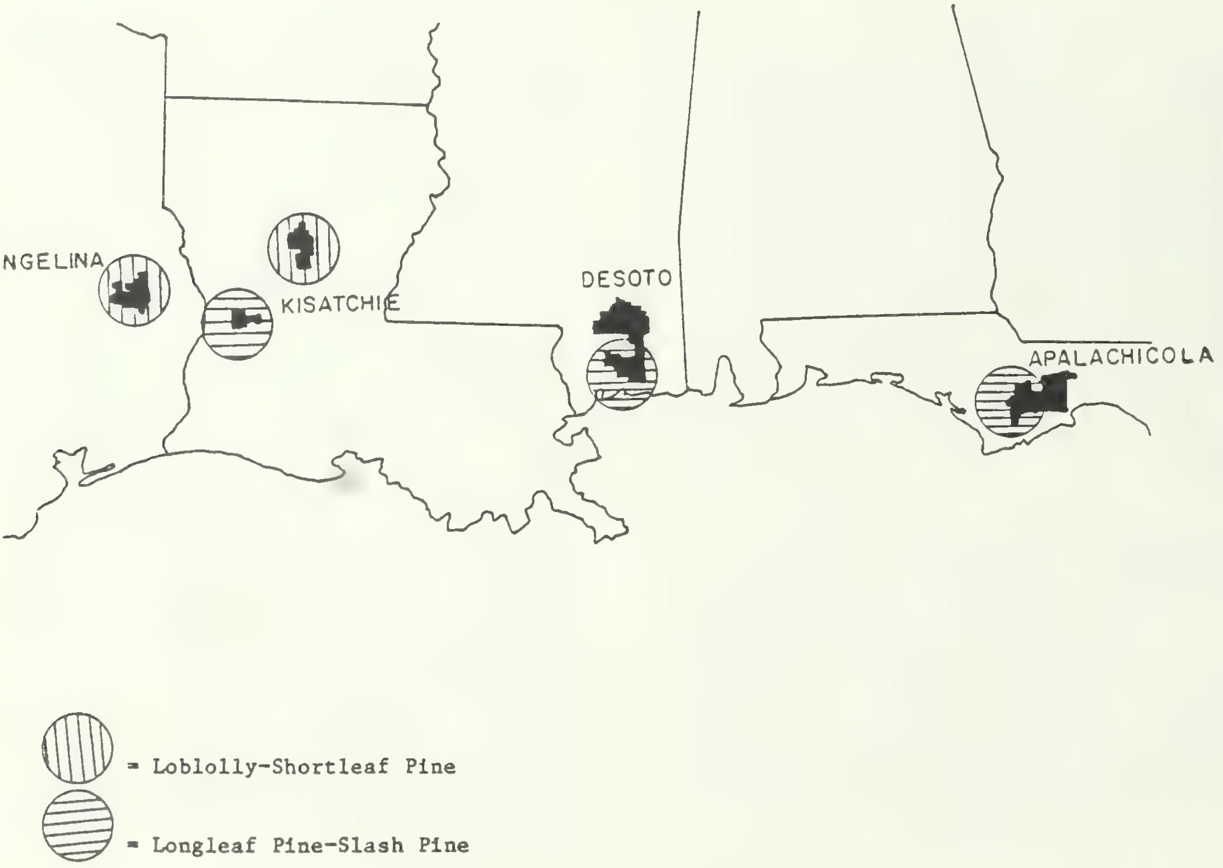

FIGURE 1. Southern Evaluation Project locations.

Table 1.--Grazing history on the Southern Evaluation Project areas

Forest type	State	National Forest Ranger District	Grazing History
Loblolly-shortleaf pine	Texas	Angelina	No grazing since 1969; controlled light grazing 1963-69; uncontrolled moderate grazing prior to 1963.
Loblolly-shortleaf pine	Louisiana	Catahoula	No grazing since 1973; light to moderate grazing since 1967; moderate to heavy uncontrolled grazing prior to 1967.
Longleaf-slash pine	Louisiana	Vernon	Moderate controlled grazing on all areas since 1967; heavy grazing prior to adjudication in 1967.
Longleaf-slash pine	Mississippi	Biloxi	Moderate grazing on three areas since 1966; no grazing on one area; uncontrolled heavy grazing by cattle and sheep on all four areas prior to 1966.
Longleaf-slash pine	Florida	Apalachicola	No grazing until 1978; moderate grazing on two areas; no grazing on two areas since 1978.

echniques were utilized at different locations to ttain comparable results where possible; however, pecific techniques and sampling intensities were etermined by the scientists in charge of the indi- idual projects. Measurements included the ollowing elements: soil, water, climate, flora, auna, and socioeconomic influences.

DISCUSSION

Soil surveys were completed on all the study reas. Watershed evaluations were performed on the ouisiana longleaf-slash pine and Texas loblolly- hortleaf pine types. Social assessments of com- unity development were conducted only in ississippi. Economic evaluations were made to ssess the forest-range livestock enterprise, lternative livestock strategy economies, and egional impacts of implementation of forest grazing programs in the South. Vegetation, amphibian, reptile, mammal, and bird measurements were completed on all the study areas. These evaluations reflect present land management and provide baseline data for future management assessments and land use planning.

The Southern Evaluation Project has resulted in 42 publications including proceedings, professional and trade journals, USDA bulletins, agricultural experiment station bulletins, and theses (Appendix I), 24 formal presentations (Appendix II), and 58 reports (Appendix III). These reports are filed at the Southern Forest Experiment Station, Range Management Research Work Unit, Pineville, Louisiana. The 32 papers published in these workshop proceedings conclude work initiated through the Southern Evaluation Project.

LOBLOLLY-SHORTLEAF PINE TYPE

Moderator:

Kent T. Adair
Stephen F. Austin State University
Nacogdoches, Texas

Loblolly-shortleaf pine-hardwood forests comprise the most extensive forest range type in the South. The area totaling about 55 million acres, reaches almost unbroken from eastern Texas to northeatern Virginia and varies from 150 to 300 miles wide.

Soils of the Loblolly-Shortleaf Pine-Hardwood Type, Angelina National Forest, Texas

Raymond Dolezel and Fred E. Smeins

Abstract.--The Texas site for the Southern Evaluation Project was a 10,665 acre area on the Angelina National Forest in East Texas. The landscape is gently rolling and varies in elevation from 150 to 400 feet. Two major geologic formations (Yegua and Cook Mountain) underlie the area. Vegetation is dominated by loblolly and shortleaf pine with admixtures of longleaf pine and various hardwoods. Soils are primarily Alfisols, Ultisols and Vertisols in the uplands and Entisols in the bottomlands. Twelve soil series were identified and a detailed soils map was prepared. Soils vary from deep sands to relatively shallow loamy sands and loams over a claypan of montmorillonitic clays. The majority of soils within the area would be considered to have moderate production potential for timber and understory plants.

INTRODUCTION

The Texas site for the Southern Evaluation Project was located on the Angelina National Forest (fig. 1) in east, central Texas within the East Texas Timberlands Resource Area (= Pineywoods) (Godfrey and others 1973, Freeouf 1977). It is characterized by mixed pine (loblolly, shortleaf, longleaf)-hardwood forests. Most upland soils are Alfisols and Ultisols, however, clayey substrates have produced Vertisols as well (Dolezel and Holt 1979). Inceptisols and Entisols occur in the bottomlands.

The purpose of this evaluation was to provide baseline soils data for proposed grazing and silvicultural treatments which were to be applied to the area. This information would provide a basis for interpretation of soil and vegetation responses to the various treatments. Specific objectives were to: 1) identify, describe and map the soils of the area at an Order 2 soil survey as defined by the Soil Conservation Service, and 2) to qualitatively and quantitatively characterize selected physical and chemical properties of selected soils and sites.

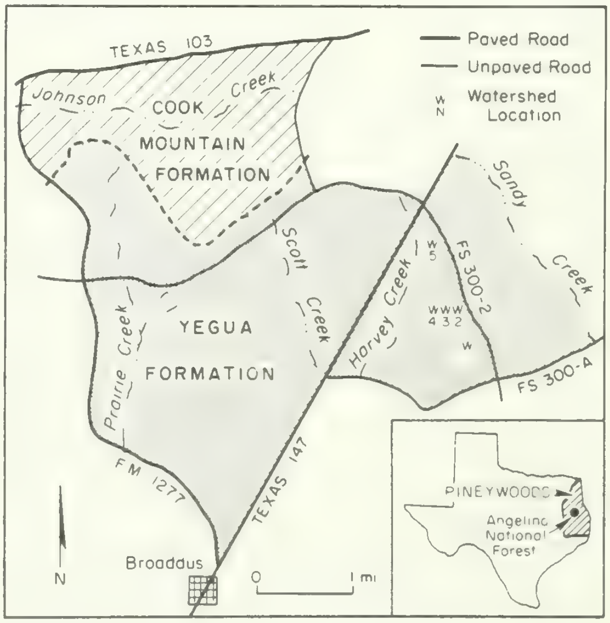

Figure 1.--Location and physical features of the Texas Southern Evaluation Project site.

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STUDY AREA

Location and Landscape

The 10,665 study area was located on the 116,000 acre Angelina National Forest in San Augustine County, Texas (centered at 94'15°W, 31° 15'N). It is approximately 30 miles east of Lufkin, Texas. The western boundary is defined by Texas Farm Road 1277, the northern by Texas Highway 103, the eastern by Sandy Creek and the southeastern by Texas Highway 147 and Forest Service Road 300-A (fig. 1).

The area is in the Gulf Coastal Plain Physiographic Province. The landscape is gently rolling and varies in elevation from 150 to 400 feet. Three perennial creeks, Prairie, Scott and Harvey, drain the southern two-thirds of the area southward into Sam Rayburn Reservoir. The northern portion is drained northward by tributaries of Johnson Creek. Other than riparian areas there are no significant wetland areas (fig. 1).

Geology

Two Eocene geologic formations underlie the area: the Yegua and the Cook Mountain (Geol. Atlas Tex. 1974) (fig. 1). The Yegua formation underlies the southern three-fourths of the area and is a heterogeneous complex of layers of sand, clay, lignite and carbonaceous clay lentils. It is essentially a piedmont of coastal alluvial fans built up by coalescing stream levees and deltas and later reinundated by the ocean. The northern part of this formation was deposited as a beach and consists of deep sand deposits. The Cook Mountain formation underlies the northern one-fourth of the area and is made up of montmorillonitic clays and fine-grained sands. It was formed from sediments of bays and shallow near-shore ocean environments. Gypsum ($CaSO_4$) and calcium carbonate ($CaCO_3$) occur variably throughout the formation (Sellards and others 1966).

Climate

The climate of the area is mesothermal, humid subtropical with rainfall throughout the year. The frost-free period is 238 days with the first frost occurring in mid-November and the last in mid-March. Mean temperatures range from 47°F in January to 82° F in July (fig. 2). Annual precipitation averages 49 inches with greater than three inches falling during each month. Approximately 25 inches of rainfall occurs in April through September which is the growing season. July and August can be dry during some years and there can be considerable year to year variation. For example, during the years of study, 1979 and 1980, total precipitation was 75 and 48 inches, respectively. June, July and August were extremely dry in 1980 and collectively these months recorded only 3.5 inches, while the same months in 1979 received 12.8 inches. Also temperatures were higher in 1980 with June, July and August averages of 81.9, 84.9 and 84.2, respectively, while averages for the same months were 78.3, 81.4 80.7.

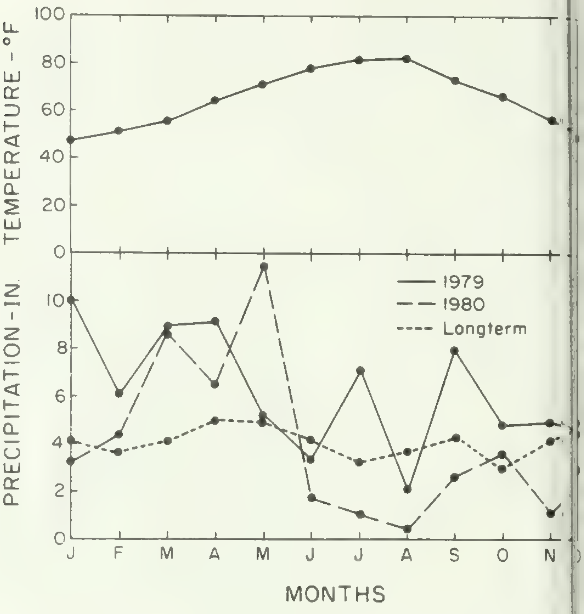


Figure 2.--Long-term temperature and precip tion and precipitation for 1979 1980.

Vegetation

Detailed analysis of the vegetation of area is presented in the following paper (Sm and Hinton, this volume). Generally, mos the area is forested with less than 5 percen clearcuts, pastures or crops. The forests second growth and most are mixtures of pines hardwoods. Loblolly pine (*Pinus tae* shortleaf pine (*P. echinata*) and longleaf (*P. palustris*) occur throughout the area associated oaks (*Quercus* sp.), sweet (*Liquidamber stryraciflua*) and other hardwoo

METHODS AND PROCEDURES

Soil Survey and Mapping

Black and white aerial photographs scale of 1:15840 (4 inches = 1 mile) take June 6, 1955, along with USGS 7.5 minute q rangle maps were obtained to provide a base for investigation of soil-topographic relat ships (Dolezel and Holt 1979). Topogra contours were identified on the photograp the first approximation of variation within area. A field reconnaissance was made of entire area by Soil Conservation Service s scientists to obtain an initial evaluatio the variety of soils to be found.

Based upon the topographic variation impressions of the field reconnaissance, uni areas within topographic contours were ide fied on the photographs for more intens tudy. Examples of all topographic-landscape ombinations were selected for study.

In the field, transects were traversed cross each identified area on the photograph nd several (a minimum of ten) soil cores were escribed for each location. Sample points on ach transect were permanently marked with white etal stakes. Cores were obtained with a 2-inch iameter hydraulic, pick-up mounted soil auger, r with a hand-operated soil auger where vehicle ccess was impossible.

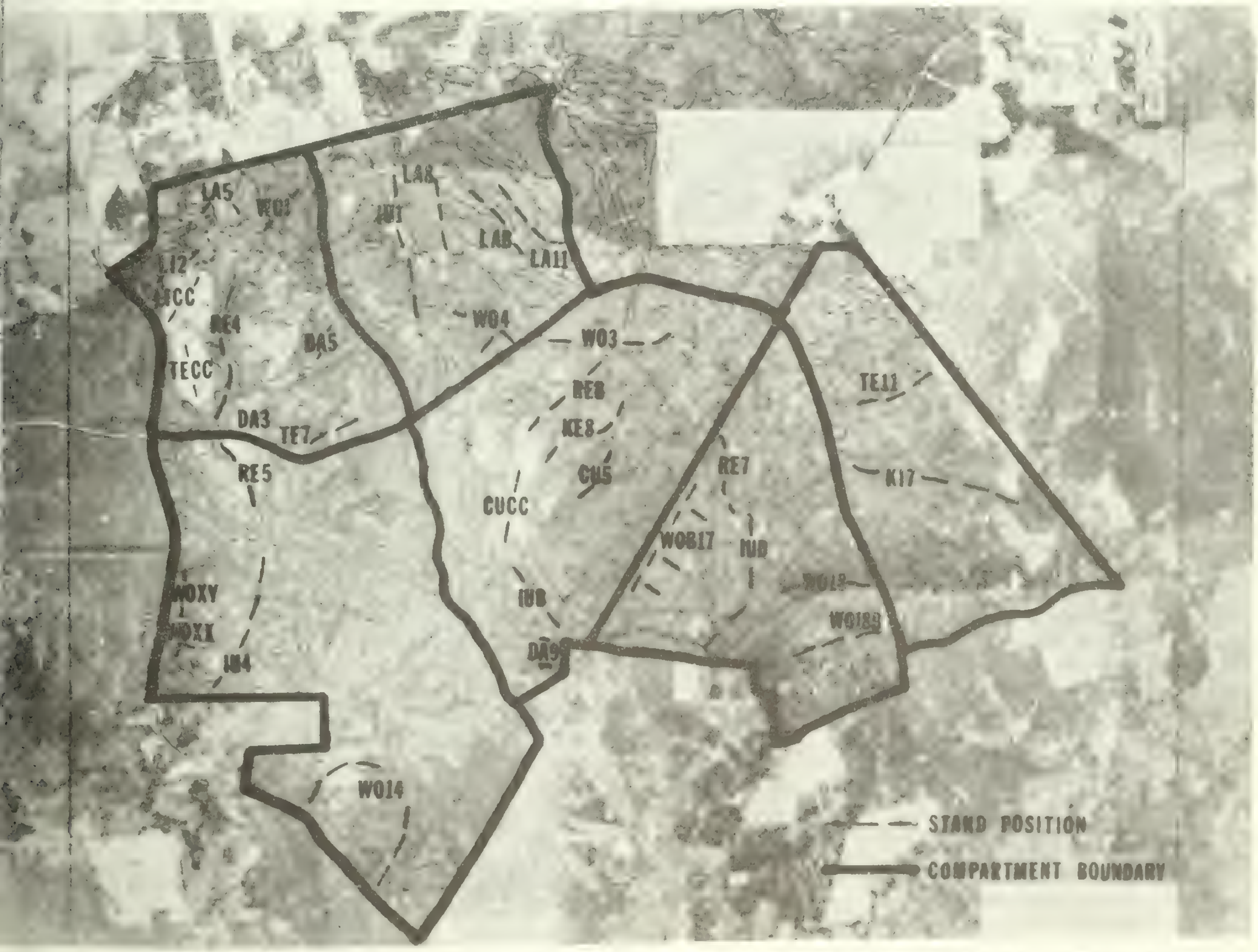
Soil profiles were described in the field nd for each horizon, color, texture, organic atter, structure, drainage regime and other bservable soil properties were qualitatively valuated. Slope, aspect, parent material, past and use and other notable features of the ample areas were recorded. Based upon field escriptions each soil was classified according o the Soil Taxonomy System (Soil Survey Staff 975).

Based upon interpretation of aerial photo- raphs and the field survey and classification f soils, a map was prepared to show the kinds nd patterns of soils that occur within the tudy area. Each map unit identified represents a soil series and as such serves as a guide to the suitability of the soil for specific uses, to identify plant production potential and to identify limitations and principal hazards to be considered in management planning. The soil survey and map preparation was conducted during 1979.

Soil Characterization

Thirty-three mapping units which represented most of the soil series identified in the area were selected for further soil analysis (fig. 3). Mapping units were selected for study if they 1) exhibited uniformity of soil features and topography, 2) had homogeneity of vegetation in all strata, and 3) were of sufficient size to obtain a representative sample and to avoid edge effects. Along the transects established across the mapping unit during the soil survey several (a minimum of 10) 0- to 6-inch soil cores were collected during August 1980. These cores were pooled to form a composite sample, placed in paper bags, transported to the laboratory and immediately air dried.

In the laboratory, texture, percent organic matter, and soil pH were determined for each sample using the hydrometer method (Day 1957),



igure 3.-- Generalized soils map of the study area with each study stand (e.g. WO14) identified within National Forest management compartments. Abbreviations (e.g. WO, RE, etc.) refer to soils described in Table 1.

Wakely-Blake method (Black and others 1965), and a HACH pH meter, respectively.

Depth to the claypan was determined in the field in each sample area using a 3/8-inch radius, 4-foot long metal rod which was incremented into 4-inch intervals. The rod was driven into the soil at several locations near each sample point, depth to the claypan was recorded for each probe and an average depth was obtained for the stand. Slope position (top, middle, bottom), aspect (compass) and inclination (abney level) were recorded for each stand.

Two replications of four soil series were selected for additional characterization. They included a Tenaha loamy fine sand, a Cuthbert fine sandy loam, a Woodtell very fine sandy loam and a Lacerda clay. Within each of these sites five samples (0-12 inches) were collected in mid-August 1980 along the established transect and pooled for later analysis. They were analyzed for pH, calcium, magnesium, phosphorus and potassium by the Soil Testing Laboratory, Texas A&M University (Chapman and Pratt 1961). Moisture release curves were determined by the Texas A&M University Forest Science Laboratory (Richards 1965). Samples were collected during August 1980.

RESULTS AND DISCUSSION

Soils of the Area

Twelve soil series were recognized within the area (table 1). For the Lacerda and Woodtell series two phases were mapped for a total of 14 soil mapping units. Upland soils are Alfisols, Ultisols or Vertisols, while bottomlands area primarily Entisols and Ultisols (table 1). Woodtell, Lacerda and Cuthbert were the predominant upland series and covered 65 percent (6,926 acres) of the total area. Rentzel and Iuka are the major bottomland soils and covered 1409 acres or 13 percent of the total area.

A reduced map of the study area with topographic contors and map units is presented (fig. 3). Maps of greater detail and clarity are available in the report by Dolezel and Holt (1979) if greater resolution is desired. Also identified on figure 3 are the specific study transects used for soils and vegetation sampling (Smeins and Hinton, this volume).

Detailed descriptions of the profile of the soils found on the area are presented elsewhere (Dolezel and Holt 1979, Dolezel and Fuchs 1980). Upland soils vary from deep sands to clays with shallow clay loam surface horizons (table 2). Darco and, to a lesser extent, Lilbert, Tenaha and Keltys soils are sandy with a relatively deep solum (table 2). Surface soil sand content exceeds 65% for all of these series. Their subsoils are loamy sands or sandy loams (fig. 4). They have medium acid surface horizons and strongly acid subsoils (table 2). Permeabil is generally rapid and moisture retention (fig. 5). These soils developed from the sa Yegua Formation with Darco soils formed on d beach deposits of this Formation (fig. 6).

Table 1.--Soil name, taxonomic class and acreage for soil typ the Southern Evaluation site, Angelina National Fo Texas. Information adapted from Dolezel and Holt 19

Soil Name and Map Unit	% Slope	Map Symbol	Acres	Taxonomic Class
Upland				
Darco lfs	1-8	Da	48	Loamy, siliceous, th mic Grossarenic Pale dults
Lilbert lfs	1-8	Li	326	Loamy, siliceous, th mic Arenic Plinthic Paleudults
Tenaha lfs	5-20	Te	634	Loamy, siliceous, th mic Arenic Hapludult
Keltys[1] fsl	1-5	Ke	584	Fine-loamy, siliceou thermic Aquic Hapludults
Kullit l	0-4	Ku	128	Fine-loamy, siliceou thermic Aquic Paleudults
Kirvin fsl	1-8	Ki	610	Clayey, mixed, ther Typic Hapludults
Cuthbert fsl	5-20	Cu	1,471	Clayey, mixed, ther Typic Hapludults
Woodtell vfsl	1-5	Wob	2,692	Fine, montmorillonit thermic Vertic Haplu dalfs
Woodtell vfsl	5-20	Wod	1,149	Fine, montmorillonit thermic Vertic Haplu dalfs
Lacerda cl	1-5	Lab	464	Very-fine, montmoril lonitic, thermic Aqu tic Chromuderts
Lacerda cl	5-20	Lad	1,150	Very-fine, montmoril lonitic, thermic Aqu tic Chromuderts
Bottomland				
Iuka fsl	0-1	Iu	457	Siliceous, thermic Psammaquents
Rentzel lfs	0-5	Re	952	Coarse-loamy, silice acid, thermic Aquic Udifluvents
Osier[2]	0-1	Os	-	Loamy, siliceous, th mic Arenic Plinthaqu Paleudults
TOTAL			10,665	

[1] Tentative series

[2] Mapped as inclusion with Rentzel

Cuthbert, Kullit, Kirvin and Woodtell soi have loamy surfaces with clay or clay lo subsoils (fig. 4). Sand content of the surfa horizon is between 60 and 70%, while subsoi tend to be clayey (table 2). Surface a subsurface horizons are strongly to ve strongly acid (table 2). Permeability moderate to moderately rapid and moisture rete tion is relatively low (fig. 5). These soi formed on clayey sediments of the Yeg Foundation and clays of the Cook Mounta Foundation (fig. 6.).

ble 2.--Mean physical and chemical soil properties of the surface soil (0-6 in) of selected soil series[1] on the Angelina National Forest study area, Texas. Samples collected in August 1980. Data adapted from Hinton 1981

	Sand (%)	Silt (%)	Clay (%)	Organic matter (%)	pH	Claypan depth (in)
lands						
rco (3)[2]	74	10	12	1.4	4.8	36
lbert (1)	71	12	17	1.8	4.9	25
naha (2)	68	12	22	1.8	4.6	18
ltys (1)	65	19	16	1.9	4.3	20
rvin (1)	63	15	22	1.8	4.4	13
thbert (1)	70	11	19	2.0	4.4	16
odtell (9)	58	17	24	1.8	4.3	10
cerda (4)	26	26	48	1.5	4.2	2
ttomlands						
ntzel (4)	71	9	10	1.8	4.1	39
ka (4)	66	15	19	1.7	4.2	35

Kullit and Osier series not evaluated

Numbers of stands sampled

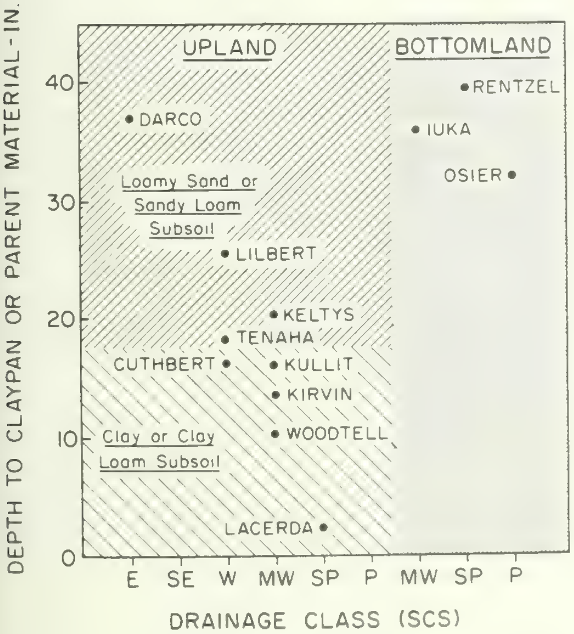


Figure 4.--Generalized diagram to illustrate the relationship of soil series to one another based upon depth to claypan and drainage class.

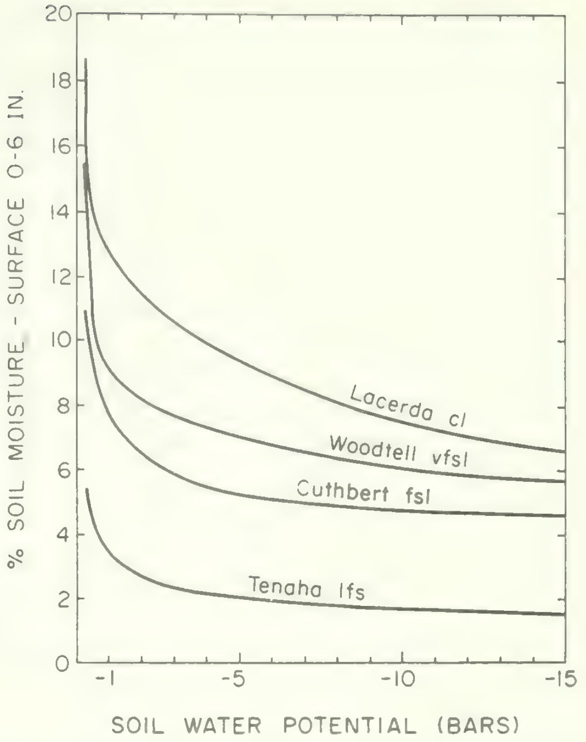


Figure 5.--Soil moisture release curves for four selected upland soil series.

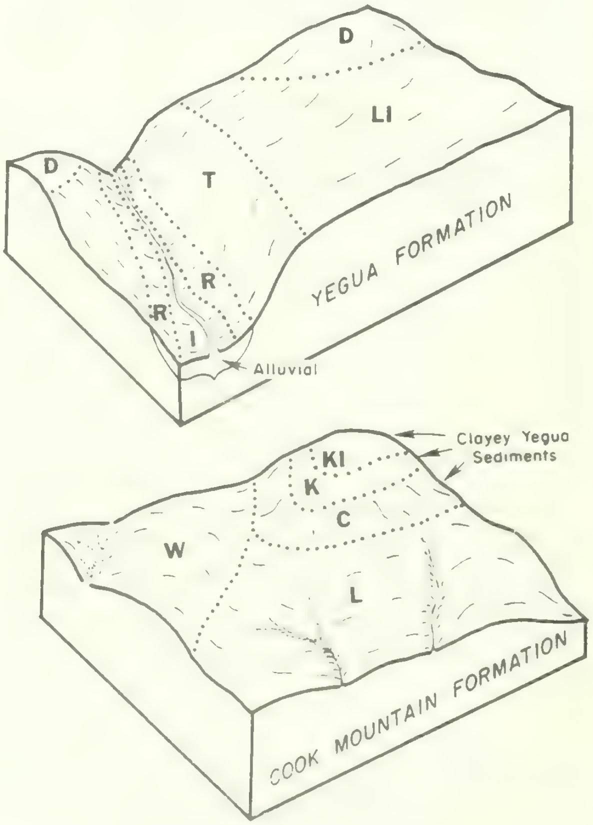


Figure 6.--The relationship of soil series of the area to geology and topography. Letters refer to series identified in table 1.

Lacerda soils are notably different from other upland series. They have a very shallow (< 3 in) clay loam surface horizon and clay subsoils (fig. 4, table 2). They are strongly acid throughout the profile. Permeability is very slow, but moisture retention is relatively high (fig. 5). These soils developed from clay deposits of the Cook Mountain Formation (fig. 6) on the northern portions of the study area (fig. 1).

Bottomland soils have a deep solum which exceeds 35 inches for all series studied (fig. 4, table 2). They have formed along Johnson, Prairie, Scott, Harvey and Sandy Creeks and their tributaries (fig. 1). These soils all experience periods of impeded drainage due to flooding or high water table. The solum is sandy loam to loam throughout. Iuka soils occur at the moderately well-drained immediate margins of the streams, while Rentzel soils form the broad, somewhat poorly-drained floodplains of the stream bottoms (figs. 4 and 6). Osier soils are found in small, usually less than one-half acre, poorly drained pockets within the Rentzel series. All bottomland series have greater than 65% sand in the surface horizon and they are strongly acid throughout (table 2).

Chemical analyses of the surface 12 inches of four upland series indicated low values of phosphorus, potassium, calcium and magnesium for the sandy series, while the clay textured Lacerda series had comparatively higher values for all cations (table 3).

Table 3.--Mean concentration (ppm) of selected nutrients within the surface (0-12 in) of four selected soil series on the Angelina National Forest, Texas. Samples collected in August 1980. Data adapted from Howell 1981

Soil Series	Phosphorus	Potassium	Calcium	Magnesium
Tenaha	1	60	360	50
Cuthbert	5	48	200	65
Woodtell	2	48	160	115
Lacerda	3	284	1600	>500

Moisture release curves of selected upland soils showed all to have limited storage capacity (fig. 5). The clay loam surface horizon of the Lacerda series had the highest retention and greatest potential storage, while the loamy fine sand of the Tenaha series had minimal ability to store significant amounts of water.

Plant production potential is variable across the soil series (table 4). For upland series the clay profiles of the Lacerda series have the lowest site index for loblolly pine, 65 feet. The relatively shallow Cuthbert and Woodtell series with clay subsoils and the deep sand Darco series have site indices of 70, while the remainder of upland soils have values of 80 to 90. Floodplain soils have site index value for loblolly pine of 80 to 100, while the waterlogged Osier series has values of about 80.

Table 4.--Estimated site index for loblolly pine and understory production for soil series within the Angelina National Forest, Texas. Data adapted from the Soil Conservation Service 1980 Soil Survey of Nacogdoches County, Texas

Soil Series	Site Index (Loblolly pine)	Woodland Understory Production (lb/acre)
Upland		
Darco	70	1,500 - 3,000[1]
Lilbert	80	1,500 - 3,000
Tenaha	80	1,250 - 2,500
Kullit	90	1,600 - 2,500
Kirvin	80	1,250 - 2,500
Cuthbert	70	1,250 - 2,500
Woodtell	70	2,000 - 3,500
Lacerda	65	1,500 - 3,500
Bottomland		
Rentzel	90	1,400 - 2,000
Iuka	100	2,000 - 5,000
Osier	80	800 - 1,800

[1] Values represent the range from unfavorable to favorable growing seasons

Understory production across all uplan series varies from 1250 to 3500 lb/acre acros years with most averaging approximately 1,800 t 2,000 (table 4). This assumes a relatively ope canopy. When canopy cover is very great understory production is greatly reduced and seldo exceeds 200 to 300 lb/acre (Smeins and Hinton this volume).

The study area is relatively representativ of the East Texas Timberlands Resource Area. It is a moderately rolling landscape with two majo geologic formations. Topography varies from 15 to 400 feet and is variable across short distances. This, along with considerabl dissection of the area by several streams, creates a diverse mosaic of soils. Soils in the uplands vary from deep sands to clays and represent primarily Alfisols, Ultisols and Vertisols. Bottomland soils are primarily Entisols with some Inceptisols and Ultisols. Within upland soil series there is moderate variation in plant production potential, however, the series that cover the majority of the landscape, that is, the Cuthbert, Woodtell, Lacerda and Rentzel series tend to be sites with lower productivity.

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Vegetation of the Loblolly-Shortleaf Pine-Hardwood Type, Angelina National Forest, Texas

Fred E. Smeins and Johnny Z. Hinton

Abstract.--The Texas site for the Southern Evaluation Project was a 10,655 acre portion of the Angelina National Forest in East Texas. The purpose of this investigation was to quantitatively describe the vegetation of the site and relate the plant communities to topo-edaphic variables of the area. Ninety-seven percent of the area is characterized by closed canopied forests of 50 to 60 year old loblolly, shortleaf and longleaf pine. Pines contribute 70% or more to the basal area in nearly all stands. Hardwoods contribute less than 40% of all dbh classes in most stands and they occur primarily in the smaller dbh classes. Three percent of the area was in 2 to 8 year old clearcuts. Composition and structure were similar across communities with subtle responses to soil texture, soil depth, drainage regime and topographic position. Longleaf pine was, for example, found throughout except on the clayey Lacerda soil series. Browse and herbage yield in forested areas was less than 400 lb/acre in any sampled stand which makes the carrying capacity for larger herbivores very low. Clearcuts yielded from 1400 to 1800 lb/acre.

INTRODUCTION

The Southern Evaluation Project in Texas was located on the Angelina National Forest which is situated in East Texas (fig. 3, Dolezel and Smeins, this volume). This was one of two loblolly-shortleaf pine-hardwood type locations designated for study in Texas and Louisiana. This paper presents vegetation data for the area and is a companion study to the preceding paper by Dolezel and Smeins which describes the soils information for the area.

The purpose of this investigation was to provide baseline vegetation and vegetation-soil-topographic relationship data for proposed grazing and silvicultural treatments which were to be applied to the area. The data would provide a base for interpretation of vegetation responses to the various treatments. Specific objectives were to: 1) provide a quantitative description of the plant communities of the area and 2) establish relationships between plant communities and associated soils, topography and land use history.

STUDY AREA

A detailed description of the physical environment of the study site is presented in the preceding paper by Dolezel and Smeins and only a brief overview is presented here. The study was conducted on a 10,665 acre portion of the Angelina National Forest in East Texas. This gently rolling portion of the Gulf Coastal Plain Physiographic Province occurs over two major geologic substrates, the Yegua and Cook Mountain Formations. The Yegua Formation produces medium to strongly acid, relatively permeable, sandy soils over claypan subsoils, while the Cook Mountain Formation gives rise to montmorillonitic clay soils which are strongly acid and slowly permeable. All soils are relatively low in fertility. Twelve soil series were identified across the area.

The climate is classified as mesothermal, humid subtropical. Mean annual precipitation is 49 inches. The growing season is 238 days. Plant communities are dominated by varying combinations of loblolly (Pinus taeda), shortleaf (P. echinata) and longleaf (P. palustris) pine with admixtures of hardwoods, primarily oaks (Quercus) and sweetgum (Liquidambar styraciflua).

The area became part of the National Forest system in 1936. No exact land use records exist prior to that time. Aerial photographs from 1942 show most of the area to have been extensively thinned or clearcut (Hinton 1981). The only continuous strips of timber occurred along stream floodplains. Since inclusion in the National Forest only a few, small, scattered areas of less than 50 acres have had timber harvested.

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No wild fires have been recorded on the area for the past 50 years. Some small segments of the study site have been subjected to prescribed burning to thin out the understory. These fires were initiated in the mid-1970's and at the time of the study less than 500 acres had been burned. No burned areas were included in this investigation. No record of grazing exists prior to 1936. From then until 1962 moderate extensive grazing occurred but no exact records exist. From 1963 to 1969 a controlled grazing plan with a light stocking rate was implemented and since 1970 no grazing has occurred. Another factor that has influenced composition and structure of these plant communities was the apparent widespread girdling in upland stands of hardwoods that had been left from earlier timber harvests or that had regrown. No exact records exist as to when and to what extent this practice was applied.

METHODS AND PROCEDURES

Sampling Design and Intensity

Based upon delineations of soil series on the soils map (fig. 3, Dolezel and Smeins), representative examples of the major soil series from across the study area were selected for evaluation. Areas selected were inspected in the field to determine uniformity of soil, slope and plant community before being utilized as a study stand. Thirty-three study sites were selected for vegetation measurements.

Once identified, the stand, depending on its size and configuration, had one to several parallel lines established across it. Along these lines 10 to 30 random sample points were selected for detailed vegetation sampling. Where possible, these lines connected already existing permanently marked soil points. Each additional sample point was marked in the same manner as the permanent soil points. The number of points sampled was determined by the size of the stand and the homogeneity of the vegetation. The location of the study stands was identified on the mosaic soil survey photograph (fig. 3, Dolezel and Smeins). A detailed description of their location and physical features is presented by Smeins and Hinton (1981).

Sample Frequency and Duration

Overstory and middlestory measurements were made during the periods of May through September, 1979 and May through July, 1980. Herbaceous and browse yield measurements were made during October, 1979 and October, 1980.

Overstory (Trees) Measurements.--At each sample point overstory woody plants (stems more than one inch dbh and greater than 5 feet in height) were sampled for:

1) basal area with a 10 factor prism (Bruce 1955)
2) canopy cover using a spherical densi meter (Lemmon 1957)
3) dbh of each stem recorded in the pri using a diameter tape
4) height of 2 to 4 canopy dominants by u of a SUUNTO clinometer
5) age of selected individuals recorded the prism by obtaining cores with increment borer
6) density of stems determined from t equation (Husch and others 1972):

$$\text{Density} = \frac{\text{basal area factor}}{0.005454\ (\text{DBH})^2}$$

7) tree classification: nonstocked wi pine regeneration (pines 3 years old younger), saplings (pines more than years old and up to 4 inches dbh), pol (pines 4-9 inches dbh), or sawtimb (pines more than 9 inches dbh)

Middlestory (Trees, Shrubs and Vines) Measurements.--Middlestory woody plants (stems le than one inch dbh and greater than 5 feet height) were sampled as follows. An 11-foot inch radius plot was established around ea sample point. Every individual of each speci was recorded and its canopy diameter and heig measured.

All Woody Plants.--A 33-foot radius pl was sampled around each point to record th presence of any woody plant of any size growth form.

Snags and Cavities.--The number of snag and cavities were recorded within the same 3 foot radius plot. A snag is any standing dea tree or part of a dead tree at least 10 inche dbh and 10 feet tall. A cavity was defined a any hole in any standing live or dead tree tha permitted use by mammals or birds.

Browse and Herbage Measurements.--Browse (current years growth from woody plants below a height of 5 feet) and herbage (current years growth of herbaceous plants to ground level) was sampled using the quadrat method. At randomly selected sample points within each stand 3, 38.5 ft^2 (3.5 ft. radius), circular plots were located at a distance of 10 feet from the sample point at random compass orientations. Al browse species and all herbaceous species were clipped separately and weighed in the fiel Selected samples were returned to the laborator for determination of percent moisture so tha all values could be reported on an oven-dr basis. A minimum 15 plots for both browse an herbaceous plants were sampled in each stand.

Other Measurements.--Within each bioma plot percentage mulch cover was estimated to th nearest 10 percent and mulch depth was measure to the nearest tenth inch.

Taxonomic Nomenclature.--Taxonomic nomenclature follows Correll and Johnston (1970) fo forbs and woody plants and Gould (1975) fo grasses. Plant names were standardized to agre with the national list of scientific plant name

eveloped by the Soil Conservation Service
971).

RESULTS AND DISCUSSION

and Summary by Soil Series

A summary of overstory and middlestory
ant characteristics for all stands is given in
ble 1. With the exception of three clearcuts
ot included in the table), measurements
hibit only slight differences between stands
d between uplands and bottomlands. Densio-
ter values ranged from 68 to 99 percent. The
jority were over 85 percent. One stand on a
ltys soil was the lowest (68%) because several
ints sampled were beside openings along an old
gging road. Basal areas were distinctly
gher in bottomland stands. Diameter at breast
ight averaged between 10 and 18 inches per
ee. On the uplands all but three Darco stands
eraged 11, 12 or 13 inches, while bottomlands
eraged 15 or 16 dbh per tree.

Density values varied across all stands
rom 286 to 778 trees per acre. Densities were
igh because all stems above 1 inch in diameter
nd 5 feet in height are included. All stands had an average age between 42 and 70 years with most between 50 and 60 years. One Rentzel stand averaged 94 years. Average overstory height ranged from 54 to 75 ft with most over 65 ft on the uplands and 89 to 96 ft on the bottomlands. Middlestory canopy (ft^2/acre) varied across all stands and ranged from 2371 to 10,560 ft^2/acre (5 to 24%). Middlestory height varied little and averaged between 7 and 8 feet across all stands.

Snags and cavities were few in number. This can be attributed to the relatively young age of the trees. Snags ranged from 0 to 4 per acre on the uplands and 1 to 2 per acre on the bottomlands, and cavities from 0 to 3 on the uplands and 3 to 11 on the bottomlands. More cavities exist on the Iuka soils because they support an older stand of beech which had many cavities near its base. Mulch cover averaged over 90 percent in most stands and mulch depth averaged near 1 inch. Number of woody species ranged from 44 to 70 with most stands having at least 50 species.

In general, all upland and bottomland stands have high canopy cover, basal area and density and may be considered overstocked for either optimum timber production or forage

Table 1.--Summary of measured plant characteristics for sampled stands on upland and bottomland soils within the loblolly-shortleaf pine-hardwood type, Angelina National Forest, Texas

	UPLAND								BOTTOMLAND	
Number of Stands	Darco (3)	Lilbert (1)	Tenaha (2)	Keltys (1)	Kirvin (1)	Cuthbert (2)	Woodtell (9)	Lacerda (4)	Rentzel (4)	Iuka (4)
Overstory Canopy (%)	85	89	92	68	94	82	88	90	91	99
Basal Area (ft^2/ac)	120	136	138	116	143	125	135	141	171	160
dbh (in/tree)	10	13	13	13	12	13	12	11	15	16
Density (per ac)	778	329	467	480	462	286	533	633	558	553
Age (yrs)	42	56	53	51	60	51	56	62	70	61
Overstory Height (ft)	54	73	71	69	73	75	72	64	89	96
Middlestory Canopy (ft^2/ac)	10560	4899	6786	3509	9270	2371	7571	10058	9426	6972
Middlestory Height (ft)	8	7	7	7	7	8	7	7	8	7
Snags (per ac)	–	4	2	–	1	–	2	1	1	2
Cavities (per ac)	–	1	1	–	–	–	2	3	3	11
Mulch Cover (%)	95	57	74	100	100	63	98	100	98	90
Mulch Depth (%)	1	1	1	1	1	1	1	1	1	1
No. Woody Species	44	46	59	59	53	50	53	57	69	70

production. Approximately 97 percent of the study area is covered with mature pole to sawtimber type forests. Less than one percent is in a sapling stage of development. Also, slightly over two percent is in a relatively recent clearcut condition (fig. 3, Dolezel and Smeins).

Composition

A total of 268 species were sampled on the study area. The number of species by growth form group was:

Trees	44
Shrubs	35
Vines	24
Grasses	37
Forbs	123
Ferns	5
TOTAL	268

Important families represented by 3 or more species of trees were Fagaceae (12), Juglandaceae (3), Ulmaceae (4) and Pinaceae (3). Shrub families with 3 or more species included Caprifoliaceae (4), Ericaceae (3) and Rosaceae (4), while vines were primarily in the Liliaceae (6) and Vitaceae (4). The gramineae had 37 species, while forb families with more than 6 species were the Compositae (45), Euphorbiaceae (7), Labiatae (9) and Leguminosae (17). Details of total species composition and their contribution to structural and biomass data for each sampled stand are presented in Smeins and Hinton (1981).

To provide a general comparison of composition of uplands and bottomlands importance values are presented for selected species averaged across upland and bottomland stands (table 2). Species of similar importance to uplands and bottomlands are: hickories (Carya ovata), ash (Fraxinus spp.), longleaf pine (Pinus palustris), loblolly pine (P. taeda) and red oak (Quercus falcata). Species of greater importance in the uplands were: flowering dogwood (Cornus florida), shortleaf pine (P echinata), blackjack oak (Q. marilandica) and post oak (Q. stellata). Red maple (Acer rubrum), American hornbean (Carpinus caroliniana), sweetgum (Liquidambar styraciflua), American beech (Fagus grandifolia), magnolias (Magnolia spp.), black gum (Nyssa sylvatica), American hophornbeam (Ostrya virginiana), white oak (Q. alba), water oak (Q. nigra) and willow oak (Q. phellos) were more important on bottomland sites.

Table 2.--Importance values[1] for selected woody species in t loblolly-shortleaf pine-hardwood type, Angelina Nation Forest, Texas

Species	Upland	Bottomla
Acer barbatum	0.3	3.0
A. rubrum	1.0	21.7
Carpinus caroliniana	1.0	17.8
Carya ovata	0.4	0.6
C. texana	4.0	2.7
Cornus florida	10.8	4.9
Fagus grandifolia	2.0	29.0
Fraxinus spp.	2.0	2.7
Ilex opaca	0.5	1.0
Liquidambar styraciflua	15.6	23.1
Magnolia grandifolia	0.1	6.0
M. virginiana	-	9.1
Nyssa sylvatica	4.8	17.0
Ostrya virginiana	0.1	10.2
Pinus echinata	78.4	8.7
P. taeda	66.9	82.7
P. palustris	36.9	47.8
Quercus alba	4.8	16.3
Q. falcata	11.1	13.5
Q. incana	0.6	-
Q. marilandica	13.6	-
Q. nigra	0.8	6.3
Q. phellos	0.6	7.9
Q. prinus	-	1.4
Q. stellata	35.6	3.1
Q. velutina	0.7	0.4
Rhus copallina	2.5	-
Sassafras albidum	0.9	2.9

[1] Importance values obtained from the sum of relative dominanc relative density, and relative frequency (rounded to neare tenth).

Table 3.--Average basal area (ft^2/ac) for selected species across soil series within the loblolly-shortleaf pine-hardwood type on the Angelina National Forest, Texas. All values recorded to the nearest whole number

	UPLAND								BOTTOMLAND	
Number of Stands	Darco (1)	Lilbert (1)	Tenaha (2)	Keltys (1)	Kirvin (1)	Cuthbert (2)	Woodtell (9)	Lacerda (4)	Iuka (4)	Rentzel (4)
Species										
Fagus grandifolia	--	--	--	--	--	--	--	--	29	6
Liquidambar styraciflua	--	3	8	7	6	5	5	2	5	9
Nyssa sylvatica	--	--	2	2	5	2	1	--	5	10
Pinus echinata	40	81	11	13	45	6	54	42	4	9
P. palustris	36	13	60	40	45	55	10	--	--	8
P. taeda	22	19	28	42	30	30	39	48	71	86
Quercus alba	--	--	1	--	1	2	2	1	7	6
Q. falcata	2	2	3	1	3	9	4	3	6	9
Q. marilandica	5	8	8	--	3	5	2	3	--	--
Q. stellata	9	3	15	6	5	7	13	9	1	1

Basal areas for selected species were averaged across soil series to depict quantitative patterns of distribution (table 3). Pine species are clearly the dominants in all stands. All pine species occur on all series except P. palustris which is absent from the clayey Lacerda soils and stream margin Iuka soils. In the uplands Liquidambar styraciflua, Quercus stellata, Q. marilandica and Q. falcata are secondary species, while in the bottomlands, Fagus grandifolia becomes an important secondary species.

Absolute frequency for selected woody plants averged by soil series shows the general response of species to soil type and to upland and bottomland topographic position (table 4). Similar patterns are reflected for trees as shown by basal area values (table 3). Most species have wide distribution across soils. A few such as Quercus incana, which is found only on deep sands, have a restricted distribution.

Shrubs which were common to both uplands and bottomlands were American beautyberry (Callicarpa americana), possum-haw (Ilex decidua), southern wax myrtle (Myrica cerifera), deerberry (Vaccinium stamineum) and arrow-wood (Viburnum dentatum). More common on uplands were haws (Crataegus spp.), yaupon (Ilex vomitoria), sparkleberry (V. arboreum) and rusty blackhaw (Viburnum rufidulum). Species frequent on bottomlands and not uplands were strawberry bush (Euonymus americanus), sebastian bush (Sebastiana fruticosa) and sweet-leaf (Symplocos tinctoria).

Vines common throughout the area are yellow jasmine (Gelsemium sempervirens), poison ivy (Rhus toxicodendron), grapes (Vitus spp.) and briars (Smilax spp.), although S. glauca and S. walteri were more frequent on bottomlands. Rattan vine (Berchemia scandans) was more common on uplands sites and partridge berry (Mitchella repens) more frequent on the bottomlands.

Biomass Relationships

Available herbage and browse was sampled October, 1979 and October, 1980. Mean total yield averaged across upland stands for October, 1979 was 144 and 86 lb/acre for woody and herbaceous plants, respectively (table 5). Corresponding values for bottomlands were 97 and 15 lb/acre. Rainfall in 1979 exceeded the average by 27.3 inches (Dolezel and Smeins, this volume) and thus, production was relatively high. In October of 1980 production values for woody and herbaceous plants were, respectively, 114 and 28 lb/acre across upland stands and 77 and 5 lb/acre across bottomland stands. Precipitation during 1980 fell below average by 10.3 inches and production values reflect this reduction. Overall production decreased 63 percent in the uplands and 72 percent in the bottomlands from October, 1979 to October, 1980. Bottomland forested sites generally produced only about one-half of forested uplands in both years.

In the uplands, biomass values from three clearcut stands (2 to 8 years since clearcutting) exceeded forested areas by approximately four times. Most forested areas had total biomass values between approximately 100 and 300 lb/acre. Clearcuts range from approximately 1400 to 1800 lb/acre.

In upland stands trees contributed most to total productivity in 1979 and 1980 (table 5). Graminoids were the next highest followed by vines and shrubs in both years. Ferns and forbs produced more green forage in 1979 (wet year) than in 1980 (dry year). Lack of precipitation in 1980 did not affect the production of trees and shrubs on upland stands. Production of vines in 1980 was nearly 50 percent less than in 1979. In upland stands forbs decreased 58%, graminoids decreased 61% and ferns decreased 95% from October, 1979 to October, 1980.

In the bottomlands woody production accounted for 87% and 95% of the total production in 1979 and 1980, respectively. Vines were the highest available green forage followed by trees and shrubs during both years. Hardest hit by the lack of moisture in 1980 were forbs and ferns. No production of ferns was recorded in 1980.

Based upon the yield values obtained stocking rates were estimated for the area (Smeins and Hinton 1981). During 1979 approximately 180 acres would be necessary to carry one animal unit for one year, while in 1979 it would have required about 285 acres. Obviously this rather closed canopy pine dominated forest produces minimal browse and herbage for animal consumption. When it is considered that pine seedlings and saplings are major contibutors to tree browse in the uplands this would further reduce the animal carrying capacity.

Species contribution to browse and herbage yield was quite variable from stand to stand. Below are listed species within each growth form class that were primary contributors to biomass yield in upland stands. Species marked with an asterisk had consistently high values across stands.

Trees:	Cornus florida, Liquidambar styraciflua, Pinus echinata, P. palustris, P. taeda*, Quercus stellata*, Rhus copallina, Sassafras albidum
Shrubs:	Callicarpa americana, Ilex vomitoria, Myrica cerifera*, Vaccinium arboreum, V. stamineum, Viburnum dentatum
Vines:	Berchemia scandens, Gelsemium sempervirens*, Rhus toxicodendron, Rubus spp*., Smilax rotundifolia, Vitus rotundifolia

Table 4.-- Absolute frequency values of seleceted trees, shrubs and vines averaged by soil series fo loblolly-shortleaf pine-hardwood type on the Angelina National Forest, Texas

	UPLAND								BOTTOMLA	
Number of Stands	Darco (3)	Lilbert (1)	Tenaha (2)	Keltys (1)	Kirvin (1)	Cuthbert (2)	Woodtell (9)	Lacerda (4)	Iuka (4)	Re (
TREES										
Acer rubrum	62	44	58	73	86	73	57	37	90	
Asimina triloba	39	44	15	26	5	20	3	1	34	
Carpinus caroliniana	--	--	--	--	--	--	9	3	86	
Carya texana	55	100	68	7	70	20	48	70	52	
Chionathus virginica	--	100	60	20	30	67	25	47	60	
Cornus florida	52	100	93	100	95	87	92	56	69	
Fagus grandifolia	10	--	--	--	25	7	1	--	68	
Ilex opaca	10	11	13	73	45	87	37	5	64	
Liquidambar styraciflua	64	100	75	80	100	93	84	47	93	
Magnolia grandifolia	--	--	3	--	--	--	4	1	55	
M. virginiana	--	--	--	--	25	--	1	--	28	
Nyssa sylvatica	20	55	50	73	95	87	71	49	81	
Ostrya virginiana	--	--	--	7	--	--	1	12	66	
Pinus echinata	100	89	73	60	100	40	99	45	21	
P. palustris	80	--	48	100	95	100	41	--	5	
P. taeda	100	78	93	93	95	87	97	93	100	
Prunus serotina	44	--	13	33	20	50	30	15	33	
Quercus alba	--	--	25	--	25	27	21	24	84	
Q. falcata	2	55	23	7	30	5	27	87	36	
Q. incana	33	67	--	--	--	--	1	--	--	
Q. marilandica	88	100	60	40	60	53	67	63	--	
Q. phellos	17	55	18	40	30	53	39	46	89	
Q. stellata	80	100	90	80	85	73	85	86	12	
Rhus copallina	75	100	48	27	55	27	73	51	10	
Sassafras albidum	100	100	68	73	75	80	38	--	29	
Ulmus alata	--	22	15	13	25	--	5	64	42	
SHRUBS										
Ascyrum hypericoides	53	22	38	13	10	7	23	26	6	
Callicarpa americana	59	89	38	60	100	33	75	81	77	
Crataegus crus-galli	--	22	20	13	25	--	44	48	3	
C. marshallii	--	--	45	33	60	20	64	71	16	
Euonymus americana	--	--	--	--	--	--	--	--	24	
Hammamelis vernalis	--	--	--	--	--	--	--	--	29	
Ilex decidua	7	27	20	--	15	13	56	55	26	
I. vomitoria	72	22	40	93	65	73	72	21	16	
Myrica cerifera	45	89	73	87	80	80	57	12	10	
Prunus mexicana	--	100	43	7	5	13	15	8	--	
Rhamnus caroliniana	23	11	43	87	20	80	19	--	20	
Sebastinana fruticosa	--	--	3	--	--	--	1	--	34	
Symplocos tinctoria	--	--	3	--	--	--	1	--	34	
Vaccinium arboreum	55	55	65	47	85	10	55	54	40	
V. stamineum	43	55	65	40	65	60	59	63	76	
Viburnum acerifolium	--	--	18	20	--	30	6	--	58	
V. dentatum	23	11	25	20	65	60	58	26	82	
V. rufidulum	48	67	60	33	45	27	65	41	16	
VINES										
Berchemia scandens	35	44	28	73	30	53	66	58	12	
Ceanothus americana	--	33	13	--	--	13	13	15	--	
Gelsemium sempervirens	69	89	73	93	95	93	90	70	72	
Mitchella repens	--	--	13	7	5	--	24	5	93	
Parthenocissus quinquefolia	15	20	35	33	5	7	46	25	34	
Rhus toxicodendron	100	100	68	87	85	100	74	92	45	
Rubus spp.	42	100	73	47	85	40	69	73	5	
Smilax bona-nox	23	33	23	7	15	7	38	43	16	
S. rotundifolia	65	44	70	67	85	60	82	44	91	
S. smallii	13	11	15	33	65	20	29	4	9	
S. walteri	19	22	38	93	55	53	24	-	72	
Vitus aestivalis	35	78	45	27	20	20	22	11	26	
V. rotundifolia	--	78	33	40	--	60	56	74	97	

Table 5.—Herbage and browse yield (lb/acre) for October 1979 and 1980 of forested upland and bottomland stands within the loblolly-shortleaf pine-hardwood type on the Angelina National Forest, Texas

	October 1979		October 1980	
UPLANDS				
Trees	77		72	
Shrubs	26		20	
Vines	41		22	
Total Woody		144		114
Graminoids	61		24	
Forbs	7		3	
Ferns	18		1	
Total Herbaceous		86		28
Grand Total		**230**		**142**
BOTTOMLANDS				
Trees	28		20	
Shrubs	11		9	
Vines	58		48	
Total Woody		97		77
Graminoids	6		4	
Forbs	5		1	
Ferns	4		0	
Total Herbaceous		15		5
Grand Total		112		82

Forbs: Desmodium sessilifolium, Eupatorium capillifolium, Solidago odora, S. rugosa, Stylosanthes biflora

Graminoids: Chasmanthium sessiliflorum*, Dicanthelium oligosanthes and others, Eragrostis spectabilis, Panicum anceps, P. brachyanthum*, Schizachyrium scoparium*

Ferns: Pteridium aquilinum*

For bottomland stands these species contributed significantly to browse and herbage yield.

Trees: Carpinus caroliniana*, Fagus grandifolia, Ilex opaca, Liquidambar styraciflua*, Magnolia grandiflora*, Quercus alba, Quercus phellos*, Symplocos tinctoria*

Shrubs: Callicarpa americana, Myrica cerifera, Vaccinium stamineum*, Viburnum dentatum

Vines: Gelsemium sempervirens*, Mitchella repens*, Smilax glauca, S. rotundifolia, Vitus rotundifolia

Forbs: Elephantopus tomentosus

Graminoids: Chasmanthium sessiliflorum, Sedge spp., Dichanthelium spp.

Ferns: Osmunda cinnamonomea*

Correlation coefficients were calculated for biomass variables against measured plant characteristics for October, 1979 and October 1980 (Smeins and Hinton 1981). Since most stands had similar values for basal area, canopy cover and other variables, most correlations were relatively low. Significant factors ($p \leq 0.05$) that negatively affected biomass across all stands were high values of canopy cover, basal area, dbh, age, middlestory canopy and overstory height. All had r values between -0.50 and -0.65. The results indicated that a mature pine dominated forest will likely have low productivity with regard to browse and herbaceous forage.

Synthesis

Upland vegetation on the study area is similar to the oak-pine forests of the upper coastal plain (Braun 1950). Bottomland vegetation resembles her southern floodplain forest. Vegetation on the area is similar to that studied by Quarterman and Keever (1962). They stated that 14 species of plants were the "core of species typical of the pine-hardwood and early hardwood communities" which they called the southern mixed hardwood forest. Twelve of their fourteen core species were present on this study area which suggests that it is closely related to their southern mixed hardwood forest. Quercus laurifolia and Carya glabra were the two species not present on the study area. Although, Quarterman and Keever (1962) stated that there was no strong influence of soil moisture on community type, Marks and Harcombe (1975) showed that a moisture gradient was the cause for high beta (between-habitat) diversity on forests of the Texas coastal plain. It is apparent from data presented here that species of the southern mixed hardwood forest on this study area follow a soil moisture gradient which incorporates the interaction of soil depth, soil texture, and topographic position.

Within the study area, little timber harvesting has occurred since the establishment of the National Forest (1936). Records show that much of the study area was severely thinned or clearcut sometime prior to 1941 (Hinton 1981). Since that time, the study area has had no burning or timber harvesting, except for a few small clearcuts during the late 1970's. Many regenerating or remnant hardwoods were girdled which has slowed the rate of hardwood ingress. Since the early 1940's the forest has regenerated itself and became dominated by pine species. The importance of pine in the present forest's overstory is apparent and ages of upland overstory dominants (pines) indicate that most individuals are between 50 and 60 years old.

Pines ranged from 60 to 91% of all individuals in all diameter classes across all soil series on upland sites, while oaks ranged from 6 to 26% (Hinton 1981). Upland pines included loblolly, shortleaf and longleaf while upland oaks included post oak, red oak and blackjack oak. On bottomland sites, pines ranged from 50 to 59% and oaks ranged from 13 to 41% of the individuals across all size classes. Bottomland sites have primarily loblolly pine and red and white oaks. Liquidambar (sweetgum) and Carya (hickory) were contributing elements on some upland sites. Magnolia (magnolia), Fagus (beech), Nyssa (blackgum) and Acer (maple) were contributing elements on bottomland sites.

Inspection of size class distribution between pines and hardwoods indicates that most pines are in the larger size classes while hardwoods have their greatest numbers in the lower size classes (Hinton 1981). These data clearly suggest that hardwoods will potentially replace or at least become co-dominant with the pines if left undisturbed. This successional trend agrees with previous observations for forests in eastern Texas (Quarterman and Keever 1962, Marks and Harcombe 1981).

The closed canopy of most stands reduces yield of herbaceous and browse species. Generally less than 300 lb/acre of forage is available. Much of this consists of pines which are relatively unpalatable to most herbivores.

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HERPETOFAUNA IN LOBLOLLY-SHORTLEAF PINE STANDS OF EAST TEXAS

R. Montague Whiting, Jr., Robert R. Fleet and Vincent A. Rakowitz

Abstract.--Amphibians and reptiles in seedling, sapling, pole and sawtimber pine stands were studied in the Angelina National Forest in eastern Texas. Amphibians (especially frogs and toads) were more abundant in winter while reptiles dominated in spring. Winter amphibians had a stronger relationship with the availability of ponds suitable for breeding than with stand age or vegetation structure. Spring amphibians were more dependent on vegetation structure. Lizards were the dominant reptile during winter. Spring reptile communities were evenly balanced between lizards and snakes. Generally, there were differences in species compositions between study areas in the amphibian and reptile communities.

INTRODUCTION

Forest habitats are essential for many ertebrates. Management for wood and other forest esources often changes forest structure. Various ertebrate species require different forest age lasses and structures (Thomas 1979). Although ildlife and timber can coexist in a managed orest (Thomas 1979), coordination of habitat and imber management is necessary, especially for any nongame wildlife species in the southern orests (Conner et al. 1975).

The objective of this study was to describe he species compositions and relative abundances f amphibians and reptiles in pine stands of 4 ifferent tree size classes within the loblolly (*Pinus taeda*)-shortleaf (*P. echinata*) ine-hardwood ecosystem in eastern Texas.

METHODS AND MATERIALS

Study areas were located within the Angelina ational Forest in San Augustine County, near roaddus, Texas. The 4 stands selected were lassified by tree size as seedling, sapling, pole nd sawtimber. Criteria for selecting and stablishing study areas have been previously escribed (Rakowitz 1983, Whiting and Fleet 1985). or reference, the study areas selected were umbered 9 (seedling), 6 (sapling), 3 (pole) and (sawtimber) by Whiting and Fleet (1985).

SAMPLING

Within each study area, 5 line transects, each 984 ft (300 m) long (Fig. 1), were positioned across contours. Transects were 164 ft (50 m) apart and at least that far from a different vegetation type. Four 33 ft (10 m) drift fences were installed at 328 ft (100 m) intervals along each transect (Fitch 1951). Funnel traps were placed on both sides and at each end of every fence, thus a total of 20 fences and 80 funnel traps per study area (Fig. 1). Additionally, 4 hardwood boards, forming artificial cover habitat, were systematically placed about each drift fence. White polyethylene vinyl sheets were placed over the traps to protect captured animals from direct sunlight.

Amphibians and reptiles in each study area were monitored winter (5 February-5 March) and spring (5 April-4 May) during 1979, 1980 and 1981, thus a total of 6 sampling periods. Winter and spring sampling periods were chosen to include peak breeding periods for amphibians and reptiles, respectively (Bishop 1943, Dickerson 1969).

Traps and boards were checked at least every other day during each 30-day sampling period. Each week, transects were walked during the day while searching 33 ft on either side of the line under logs, rocks, discarded metal, cardboard, and in the open for reptiles and amphibians. Also each week, male frogs and toads in breeding choruses were censused along each

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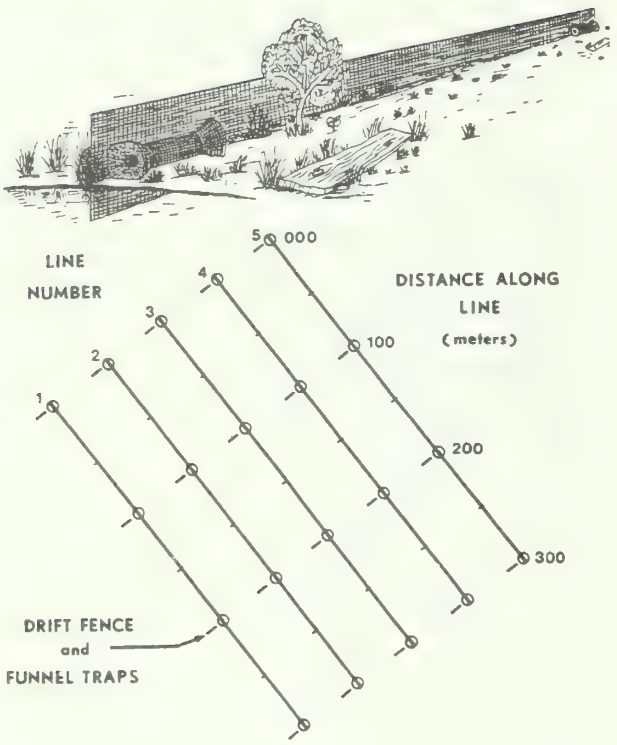

Figure 1. Schematic diagram of drift fence placement along transect lines and funnel traps and artificial cover about the drift fence.

transect line at night.

Captured animals were marked by toe clipping frogs, toads, salamanders and lizards (Martof 1953), heat branding snakes (Clark 1971), or notching the carapace of turtles (Cagle 1939). Marked animals were released at the point of capture.

Plant communities of each study area were surveyed during summer 1980. Percent coverage parameters, including ground cover by type, understory cover by type, overhead obscurity and foliage density and characteristics of small and large vegetation were evaluated. Vegetation and soil survey methods are described elsewhere (Dolezel and Holt 1979, Rakowitz 1983, Whiting et al. 1983, Whiting and Fleet 1985); weather data were taken from U.S. Forest Service records, Lufkin, Texas.

Statistical Analyses

Abundance (numbers of individuals), species richness (numbers of species), species diversity (Shannon and Weaver 1963) and equitability (Pielou 1966) were computed for pines, hardwoods and their combination for both small and large vegetation. The Pearson chi-square test of homogeneity (Dixon and Brown 1981) and Kruskal-Wallis one-way analysis of variance by ranks (Nie and Hull 1981) with multiple comparisons (Daniel 1978) were used to test differences in vegetation and soil characteristics between the study areas.

Species compositions of the amphibian and reptile communities were compared between stud areas using the Pearson chi-square test of homogeneity. The same tests were used to comp the lizard and snake communities between study areas during spring. Abundance, species divers and equitability of amphibians and reptiles an abundance of individuals by herpetofauna taxa (i.e. salamanders, frogs and toads, turtles, lizards, snakes) were compared between study areas using Kruskal-Wallis one-way analysis of variance by ranks with multiple comparisons.

The null hypothesis of no difference betw groups was used and a significance level of 0. was accepted for chi-square and Kruskal-Wallis tests. The "experimentwise error rate" was se at p=0.30 for comparing the mean ranks of grou (Daniel 1978).

DESCRIPTION OF THE STUDY AREAS

Soils

Surface soil type was visually determined and selected areas had relatively sandy surface layers. Although the percentages of soil types were significantly different between the study areas (Rakowitz 1983), soil texture, permeability, drainage and water capacity, percent slope and erosion hazard were similar (Dolezel and Holt 1979).

Vegetation

The seedling study area contained no trees with a diameter at breast height (dbh) greater than 4.0 inches (100 mm). During the study, ma planted pine seedlings died due to drought and/ damage by leaf-cutter ants (*Atta texana*). The dominant species was shining sumac (*Rhus copallina*) which comprised 42% of the plants present (Rakowitz 1983, Whiting and Fleet 1985).

The sapling area was characterized by a hi density of sapling pines (>4" dbh). No trees were designated as dominants or as midstory due to crowding into 1 height level. Dominant species in the understory were blackberry (*Rubu* spp.) and poison ivy (*Toxicodendron radicans*).

The pole and sawtimber study areas were characterized by a progressive trend toward increased height and dominance of the pines wit increased stand age. The pole stand understory had large numbers of open patches dominated by loblolly pine seedlings. The open patches were due to southern pine beetle (*Dendroctonus frontalis*) spots and old logging roads. The sawtimber understory was dominated by dense patches of poison ivy. Woody vines were more prevalent than in the other study areas.

Comparisons Between Study Areas

The most contrasting vegetation characteristics between study areas were the differences in the percentages of understory an ground cover. As successional patterns changed with increasing age, the open canopy with high percentages of bare soil and grasses shifted toward a dense canopy and the accumulation of a substantial litter layer. Since most amphibians and reptiles are terrestrial, these variations had a strong influence on the structure of the herpetofauna communities in the stands. Rakowitz (1983) and Whiting and Fleet (1985) compared the vegetation of the study areas in detail.

RESULTS AND DISCUSSION

A total of 649 amphibians of 15 species and 764 reptiles of 23 species were recorded during the 3 year study. The buttermilk snake and the southern black racer were treated as separate species. Amphibians (especially frogs and toads) were more abundant in winter while reptiles dominated spring samples. A notable seasonal difference was the emergence of box turtles during spring. Herpetofauna found in the study are classified in Table 1.

Winter Herpetofaunal Communities

During the 3 winter censuses, 462 amphibians of 10 species and 210 reptiles of 15 species were recorded.

Amphibians.--Total numbers of amphibians recorded across stand ages created a U-shaped pattern (Table 2). Species compositions of amphibian populations were significantly different between areas as were differences in abundances and species diversity and equitability values, and in numbers of frogs and toads (Rakowitz 1983). Although species compositions of the study areas were different, occurrence and abundance during winter appeared to be more strongly related to the availability and longevity of intermittent ponds suitable for breeding than to stand age.

The greatest numbers of amphibian species and individuals were encountered in the seedling study area (Table 2) which was adjacent to a large natural pond. Amphibians recorded in this area (especially frogs and toads) were presumed to be migrating toward the pond. The sapling and sawtimber areas also contained intermittent ponds; however, these were not as large or persistent as the seedling area pond. Although the pole area contained several intermittent streams, these drained rapidly after rainfall and provided very limited suitable amphibian breeding habitat. As a result, the numbers of frogs and toads recorded in the pole study area were significantly lower than in the other study areas.

Reptiles.--During winter, species compositions of reptiles were significantly different among study areas; reptile populations were different in abundances, with significantly fewer individuals recorded in the pole study area. Three species did show trends in numbers across the stands (Table 2). Northern fence lizards were most abundant in the seedling area. This species prefers dry, sandy, open woods (Smith 1946). Ground skinks were progressively more abundant in the older stands where greater percentages of litter and increased numbers of decaying logs provided cover and foraging sites (Smith 1946). Semi-arboreal green anoles increased in numbers in the older stands which contained higher densities of shrubby understory vegetation greater than 4.5 ft in height.

Forty-two southern coal skinks were recorded during winter samples while only 2 were recorded during spring samples. This suggests that the species is adapted to an annual winter activity cycle which is different from that of other Eumeces. The reason for the disproportionately large numbers in the sapling stand was not clear.

Eastern hognosed snakes were the most common snake recorded during winter sampling. Winter activity by this species is probably an adaptation to syncronize with prey activity. Hognosed snakes dig food items, primarily toads, from burrows in the soil. It is not a coincidence that the largest numbers of this snake, both in winter and spring, were recorded in the sapling area which also had the greatest number of Hurter's spadefoot toads, a large burrowing toad.

Winter reptile populations were probably strongly influenced by fluctuations in temperatures. Lizards, with small, easily heated biomass, were able to become active in and exploit short periods of warm weather within the otherwise cold regime. Thus lizards were disproportionately represented in the winter sample when compared with snakes.

Snakes, of larger biomass, were at a thermal disadvantage during winter and were generally unable to become active during brief warming periods. The greater numbers of individuals and species of snakes recorded in winter were from the seedling and sapling study areas. These study areas accounted for 32 individuals of 9 species whereas only 9 individuals of 2 species were recorded in the pole and sawtimber study areas (Table 2). Greater snake activity within the seedling study area probably resulted from higher soil temperatures due to greater solar radiation through the reduced vegetation canopy. Feeding hognosed snakes accounted for the high numbers in the sapling study area.

Spring Herpetofaunal Communities

Five hundred fifty-four reptiles of 22 species and 187 amphibians of 14 species were recorded during the 3 spring censuses. The seedling study area contained the greatest abundance of both amphibians and reptiles (Table 2).

Amphibians.--Species compositions of amphibians were significantly different between the study areas (Rakowitz 1983); spring amphibian populations were significantly different in abundances only.

Amphibians were less than half as abundant in the spring censuses as in winter censuses although more species were recorded. During spring, the majority of animals were trapped rather than recorded by call counts. Since most spring amphibians were in the post-breeding condition, they were less dependent on water and were probably foraging or migrating when captured. Although the seedling area had the greatest numbers, the numerical differences between the

Table 1. Class, order, family, scientific and common names of amphibians and reptiles recorded on the study areas (Conant 1975).

Classification	Common name
Class Amphibia	
Order Caudata	
Family Ambystomatidae	
Ambystoma maculatum	spotted salamander
Ambystoma opacum	marbled salamander
Ambystoma talpoideum	mole salamander
Family Plethodontidae	
Eurycea quadridigitata	dwarf salamander
Order Anura	
Family Pelobatidae	
Scaphiopus holbrooki hurteri	Hurter's spadefoot toad
Family Hylidae	
Acris crepitans crepitans	northern cricket frog
Hyla chrysoscelis	southern gray treefrog
Hyla crucifer crucifer	northern spring peeper
Pseudacris triseriata feriarum	upland chorus frog
Family Bufonidae	
Bufo valliceps valliceps	gulf coast toad
Bufo woodhousei woodhousei	Woodhouse's toad
Family Ranidae	
Rana catesbeiana	bullfrog
Rana clamitans clamitans	bronze frog
Rana utricularia	southern leopard frog
Family Microhylidae	
Gastrophryne carolinensis	eastern narrow-mouthed toad
Class Reptilia	
Order Testudines	
Family Emydidae	
Terrapene carolina triunguis	three-toed box turtle
Terrapene ornata ornata	ornate box turtle
Order Squamata	
Family Iguanidae	
Anolis carolinensis carolinensis	green anole
Sceloporus undulatus hyacinthinus	northern fence lizard
Family Scincidae	
Eumeces anthracinus pluvialis	southern coal skink
Eumeces fasciatus	five-lined skink
Eumeces laticeps	broadhead skink
Scincella lateralis	ground skink
Family Teiidae	
Cnemidophorus sexlineatus sexlineatus	six-lined racerunner
Family Colubridae	
Coluber constrictor anthicus	buttermilk snake
Coluber constrictor priapus	southern black racer
Elaphe obsoleta lindheimeri	Texas rat snake
Heterodon platyrhinos	eastern hognosed snake
Lampropeltis calligaster calligaster	prairie kingsnake
Lampropeltis getulus holbrooki	speckled kingsnake
Masticophis flagellum flagellum	eastern coachwhip
Natrix erythrogaster flavigaster	yellow-bellied water snake
Opheodrys aestivus	rough green snake
Thamnophis proximus proximus	western ribbon snake
Thamnophis sirtalis sirtalis	eastern garter snake
Family Elapidae	
Micrurus fulvius tenere	Texas coral snake
Family Viperidae	
Agkistrodon contortrix contortrix	southern copperhead
Agkistrodon piscivorus leucostoma	western cottonmouth

Table 2. Numbers of individual herptiles per species recorded on the seedling, sapling, pole and sawtimber study areas during winter and spring censuses of 1979-1981.

	Numbers of individuals										
	Winter					Spring					
Taxa	Seed	Sapl	Pole	Sawt	Total	Seed	Sapl	Pole	Sawt	Total	Study total
AMPHIBIANS											
Dwarf salamander	1	3	13	6	23	–	–	2	4	6	29
Marbled salamander	–	–	2	11	13	1	1	–	3	5	18
Mole salamander	8	–	–	2	10	15	–	–	–	15	25
Spotted salamander	7	1	–	–	8	–	–	–	–	–	8
Bronze frog	–	–	–	–	–	9	–	–	–	9	9
Bullfrog	–	–	–	–	–	1	–	–	–	1	1
Upland chorus frog	7	2	1	32	42	–	–	–	1	1	43
N. cricket frog	9	1	–	–	10	1	–	–	1	2	12
S. gray tree frog	–	–	–	–	–	14	11	15	8	48	48
S. leopard frog	94	5	4	3	106	7	4	8	–	19	125
Gulf coast toad	–	–	–	–	–	1	–	–	–	1	1
Hurter's spadefoot toad	5	59	–	1	65	3	17	1	1	22	87
E. narrow-mouth toad	–	–	–	–	–	5	4	3	4	16	16
Woodhouse's toad	1	–	–	7	8	2	2	9	4	17	25
N. spring peeper	115	18	–	44	177	15	3	–	7	25	202
No. Species	9	7	4	8	10	12	7	6	9	14	15
No. Individuals	247	89	20	106	462	74	42	38	33	187	649
REPTILES											
Ornate box turtle	–	–	–	–	–	1	1	1	–	3	3
Three-toed box turtle	–	–	–	–	–	2	5	7	1	15	15
Green anole	1	11	7	17	36	5	9	11	12	37	73
N. fence lizard	38	3	–	–	41	109	14	2	–	125	166
Six-lined racerunner	–	–	–	–	–	38	1	–	–	39	39
Broadhead skink	–	–	–	1	1	–	–	8	7	15	16
Five-lined skink	–	1	–	3	4	–	5	10	23	38	42
Ground skink	4	5	13	23	45	5	19	54	55	133	178
S. coal skink	1	37	3	1	42	–	1	1	–	2	44
S. black racer	1	1	–	–	2	–	2	2	–	4	6
E. coachwhip	–	–	–	–	–	2	–	–	–	2	2
S. copperhead	–	4	2	6	12	1	23	15	23	62	74
W. cottonmouth	–	–	–	–	–	–	–	1	–	1	1
Prairie kingsnake	1	–	–	–	1	3	–	–	–	3	4
Speckled kingsnake	–	–	–	–	–	1	–	–	–	1	1
Buttermilk snake	3	1	–	–	4	14	9	3	–	26	30
Texas coral snake	1	–	–	–	1	4	4	3	1	12	13
E. garter snake	–	1	–	–	1	–	–	–	–	–	1
Rough green snake	–	1	–	–	1	–	1	1	–	2	3
E. hognosed snake	3	14	1	–	18	5	12	1	5	23	41
Texas rat snake	–	–	–	–	–	1	1	1	1	4	4
W. ribbon snake	1	–	–	–	1	5	–	–	–	5	6
Yellow-bellied water snake	–	–	–	–	–	1	–	1	–	2	2
No. Species	10	11	5	6	15	16	15	17	9	22	23
No. Individuals	54	79	26	51	210	197	107	122	128	554	764
Total Species	19	18	9	14	25	28	22	23	18	36	38
Total Individuals	301	168	46	157	672	271	149	160	161	741	1413

areas were much reduced, reflecting the reduced role of the breeding pond. This does suggest, however, that the seedling study area provided optimum habitat for a wider array of amphibians than did the other study areas. For example, mole salamanders were recorded exclusively in the seedling area during spring. As terrestrial adults, they are found in ground burrows in loose sand, or under logs, debris or leaf litter (Bishop 1943, Hardy and Raymond 1974).

Reptiles.--During spring, species compositions of reptiles were significantly different between study areas as were numbers of individual reptiles and numbers of lizards (Rakowitz 1983). The seedling study area had a greater number of reptiles than did the other study areas (Table 2).

For lizards, species compositions of the seedling and sapling study areas were significantly different from each other and from the pole and sawtimber study areas. Species compositions of the latter 2 study areas were not different. The differences were probably due to differences in ground cover and density of the understory and overhead foliage. Six-lined racerunners were most abundant in the seedling area (Table 2); it contained high percentages of bare soil and vegetative ground cover, necessary for burrowing and foraging, respectively. This lizard is characterized by a high metabolic rate and requires high temperatures to be active (Smith 1946). It is not surprising that this species was found only in spring. As with winter censuses, northern fence lizards were abundant in the seedling area. Abundance of insect prey may have been responsible for the relatively high numbers of this species. Both species are typical of early successional stages and were found in decreasing numbers or were absent in the older stands.

Four of the lizard species observed are adapted to mature forests (Smith 1946, Conant 1975). As with winter, numbers of green anoles and ground skinks captured in spring increased with stand age (Table 2). Five-lined skinks and broadhead skinks are also climbing lizards, and prefer dead trees with loose bark as foraging sites and cover. These species were absent from the seedling area and generally increased in numbers in the older study areas.

Substantially greater numbers of individuals and species of snakes were recorded during spring than during winter (Table 2). The southern copperhead was the most commonly encountered snake; buttermilk snakes ranked second. Eastern hognosed snakes dropped from most abundant in the winter sample to third in spring; its numbers in the sapling stand were associated with the large numbers of spadefoot toads. During spring, snake species composition of the seedling study area proved to be significantly different from those of the other stands. Species compositions of the sapling, pole and sawtimber study areas were not different from each other.

Herpetofaunal Community Changes Over Time

A general drying trend persisted during the 3 years of the study (Rakowitz 1983, Whiting and Fleet 1985). Likewise, East Texas was subjected to a severe heat wave and drought during summer 1980. Due to high mortality of the planted pine seedlings, the seedling stand was burned and replanted between the 1979 and 1980 censuses and replanted again between the 1980 and 1981 censuses. These factors definitely impacted the herpetofaunal communities.

Winter.--Increasing drought conditions had the most severe impact on winter amphibians. Although numbers of species remained relatively constant over the 3 year study period (Table 3) numbers of individuals declined, especially in the seedling and sapling study areas (Fig. 2). These declines were a result of reduced breeding sites.

During 1979, each study area had potential breeding sites. The pond associated with the seedling area attracted a variety of species. Rainfall filled intermittent ponds on the sapling area where a breeding aggregate of 37 Hurter's spadefoot toads were recorded 2 days after an intense rainfall followed by a warming trend. This species is stimulated by heavy rains during warm periods, emerging in great numbers to migrate to breeding pools (Porter 1967, Conant 1975). Even with the high moisture conditions of 1979, low numbers of salamanders, frogs and toads in the pole study area were probably due to a lack of adequate breeding sites. Dwarf salamanders, which are mostly terrestrial (Bishop 1943), were captured in the pole study area under artificial cover in relatively moist sites adjoining an intermittent stream. Intermittent streams on the sawtimber study area contained numerous persistent pools that attracted toads and frogs (Rakowitz 1983). The lack of salamanders on that stand (Table 2) seemed unusual since there was abundant suitable habitat (rotting logs, leaf litter, debris, ponds).

Winter 1980 was considerably drier than winter 1979. The only rainfall during the census period was accompanied by a decrease in air temperature which eliminated most herpetofaunal activity. Relatively dry conditions eliminated intermittent ponds in the sapling and sawtimber stands. Although reduced in size, the pond in the seedling area accommodated a moderate population of amphibians.

There was a significant decrease in abundance of amphibians in comparison with the 1979 winter sample. No frogs or toads were recorded in the sapling study area. Also, there was a 50% reduction in frog and toad numbers in the seedling area. Noticeable in the seedling study area was the presence of marbled salamanders, which frequent drier habitats than other salamanders, and the absence of mole salamanders. Reduced overall numbers may also have been the result of mortality due to habitat disturbance by prescribed burning in December 1979 and machine planting of pine seedlings in January 1980.

Table 3. Numbers of species and individuals of amphibians and reptiles recorded on the seedling, sapling, pole and sawtimber study areas during each sampling period. Significant differences between stands by sampling period are also noted.

	Winter					Spring					Yearly
Taxa	Seed	Sapl	Pole	Sawt	Total	Seed	Sapl	Pole	Sawt	Total	total
						1979					
AMPHIBIANS											
No. Species	8	8	1	5	9	7	4	4	4	10	14
No. Indivi.	143	81	2	53[a]	279	23	28	7	10	68	347
REPTILES											
No. Species	6	6	3	4	10	8	10	10	6	15	17
No. Indivi.	31	19	5	9	64	78	38	44	23[a]	183	247
ALL HERPTILES											
No. Species	14	14	4	9	19	15	14	14	10	25	31
No. Indivi.	174	100	7	62	343	101	66	51	33	251	594
						1980					
AMPHIBIANS											
No. Species	6	1	2	4	7	7	3	5	5	11	13
No. Indivi.	66	2	9	23[a]	100	45	5	23	20[a]	93	193
REPTILES											
No. Species	2	8	3	3	9	12	10	12	8	18	19
No. Indivi.	7	26	10	29	72	59	32	43	75	209	281
ALL HERPTILES											
No. Species	8	9	5	7	15	19	13	17	13	29	32
No. Indivi.	73	28	19	52	172	104	37	66	95	302	474
						1981					
AMPHIBIANS											
No. Species	5	2	4	7	10	3	4	4	2	5	12
No. Indivi.	38	8	9	30	85	7	9	8	3	27	112
REPTILES											
No. Species	8	7	4	6	12	11	9	9	6	19	21
No. Indivi.	16	34	11	14	75	60	37	36	31	164	239
ALL HERPTILES											
No. Species	13	9	8	13	22	14	13	13	8	24	33
No. Indivi.	54	42	20	44	160	67	46	44	34	191	351

[a] Denotes significant differences ($p < 0.05$) between stands by season. See Rakowitz (1983) for study area rankings.

Although 1981 abundances of amphibians were lower than 1980, the difference between years was not significant. Numbers of individuals in the seedling area declined, probably due to the diminished influence of the pond and the tree planting operation in January 1981. There was a slight increase in numbers of individuals in the sapling and sawtimber study areas. The high number of species in the sawtimber area was due to increased occurrence of salamanders (Rakowitz 1983). This was the only winter sampling period during which abundances of amphibians between the study areas were not different.

Numbers of winter reptiles showed no strong patterns across the 3 years (Fig. 2). In the seedling study area, numbers of reptile species and individuals decreased from 1979 to 1980, then increased from 1980 to 1981. This suggests that the combined effects of the prescribed burn and the tree planting between 1979 and 1980 were more detrimental to reptiles than tree planting only, which occurred between 1980 and 1981.

Abundances in the older stands generally increased over the 3 years. As a result, total numbers of reptiles recorded did not vary among years (Fig. 2). However, snake populations of all areas increased in 1981 when compared to the previous winters (Rakowitz 1983), probably due to warm temperatures during late February which stimulated an earlier emergence.

Spring.--Abundances of amphibians recorded during spring were consistently lower than during winter. However, during 1979 and 1980, numbers of species were higher (Table 3). Total numbers of individual amphibians showed a different trend across years during spring than winter (Fig. 2). Although amphibians are less dependent on water for breeding during spring than winter, changes in abundances across years were related to moisture conditions.

During 1979, some spring amphibians were associated with breeding sites. Chorusing southern gray treefrogs were recorded on the seedling and sapling study areas, as were

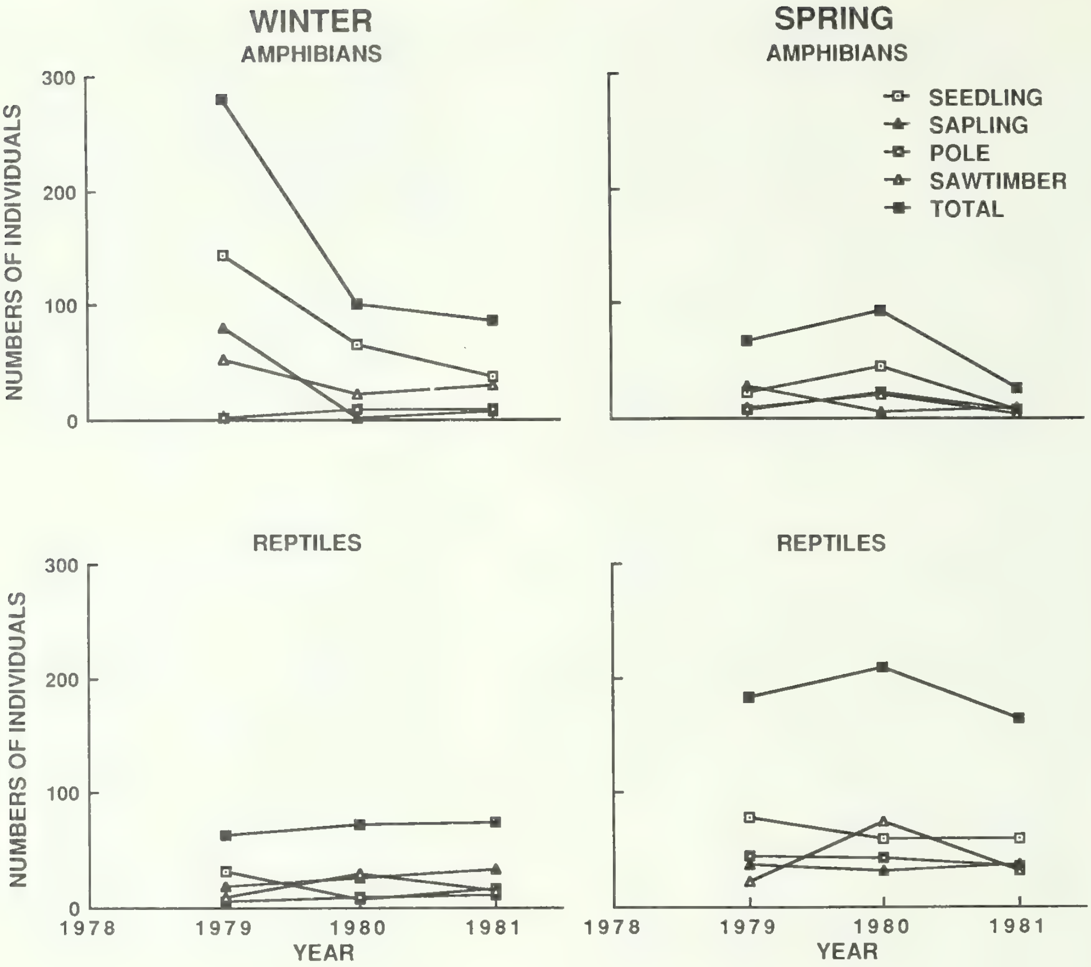

Figure 2. Relationships in numbers of amphibians and reptiles recorded during winter and spring samplin periods in 1979, 1980 and 1981.

Hurter's spadefoot toads on the sapling stand. On the droughty seedling study area, presence of eastern narrow-mouthed toads, which prefer moist sites (Conant 1975), was due to the abundance of ants. As a result of the relatively low amphibian numbers recorded, differences among study areas were not significant.

During 1980, greater numbers of individual amphibians were recorded in the seedling, pole and sawtimber study areas than during 1979. Although total precipitation declined, a heavy March rainfall recharged intermittent ponds on the seedling and sawtimber study areas. The increased number of amphibians on the pole stand may also have been due to that rain. Lack of rainfall during the actual study period prevented the emergence of spadefoot toads in the sapling study area; as a result, the number of individuals recorded there declined. The abundance of amphibians in the seedling study area was significantly greater than in the sapling and pole study areas, but not different from the sawtimber study area. Abundances in the sapling, pole and sawtimber areas were not significantly different.

During 1981, total numbers of individual amphibians were significantly lower than during 1980. Except the sapling study area, where low numbers were recorded both years, numbers of both species and individuals declined. Decline in numbers were due to the drought. Few breeding amphibians were noted in 1981, especially in the seedling study area (Table 3) However, more eastern narrow-mouthed toads were captured during this period than any other (Rakowitz 1983). Amphibian abundances between study areas were not significantly different in 1981.

Reptiles were more abundant during spring than winter in all study areas each year. Durin spring 1979 and 1981, more individuals were recorded in the seedling study area than in the other study areas (Table 3). During 1979, significantly more individuals were recorded in the seedling study area than in the sapling and sawtimber study areas. This was a result of hi numbers of northern fence lizards, which represented approximately 80% of the spring 197 reptile sample, and six-lined racerunners (Rakowitz 1983). The conditions of the seedling study area seemed to provide ideal habitat for those species (Smith 1946).

During spring 1980, reptile populations of the 4 study areas were not significantly different. This was due to a more even distribution in numbers of snakes between study areas and the decrease in numbers of lizards in the seedling area (Table 2). Reduced numbers of fence lizards and racerunners were probably a result of the tree planting activities. The increase in reptile abundance of the sawtimber study area from 1979 to 1980 (Fig. 2) was the result of a fourfold increase in ground skinks (Rakowitz 1983), for which that stand contained excellent habitat (Smith 1946).

Overall reptile abundance decreased approximately 22% from 1980 to 1981. The decrease was concentrated in the pole and sawtimber stands; there were slight increases in the seedling and sapling stands. Ground skinks in the sawtimber stand were rare; only 3 were captured, compared to 42 in 1980 (Rakowitz 1983). Two relatively aquatic snakes were captured in the pole area, a yellow-bellied water snake and a western cottonmouth. Both specimens were probably foraging out of the preferred habitat. These findings suggest that the drought had a greater negative impact on the reptile communities of the pole and sawtimber stands than on the seedling and sapling stands.

CONCLUSION

Species compositions and numbers of individuals of the amphibian communities were significantly different between the seedling, sapling, pole and sawtimber study areas during both seasons. The winter amphibian populations were probably more closely related to availability of ponds suitable for breeding than to stand age or vegetation structure. Most winter records of amphibians were from breeding choruses or aggregations. The fewer spring records were primarily captures of foraging or migrating individuals. Abundances of spring amphibians were more closely related to vegetational structure and thus stand age than were winter amphibian abundances.

Based on different ecological strategies, the reptile community can be divided into lizards and snakes. In winter, lizards, of small biomass, became active during brief warm periods and were numerically over-represented when compared with snakes. Amount of canopy closure affects soil warming, so vegetation structure probably affected the amount of winter snake activity. As a result, numbers of snakes recorded in the older stands were low during winter.

Temperature was not a factor affecting reptile abundances in the spring. Lizard populations were significantly greater in the seedling study area than in other study areas. Lizard species demonstrated both a functional and a numerical response to changing habitat conditions. High numbers of individuals of species adapted to early succession vegetation (six-lined racerunners, northern fence lizards) were responsible for the significantly greater lizard abundance in the seedling study area. Lizard species better adapted to older forest stands (green anoles, five-lined skinks, broadheaded skinks, ground skinks) were represented in greater numbers in the older stands.

The spring snake community did not show significant differences in total numbers between study areas. There were, however, differences in species composition. The seedling study area had more species and a more even distribution of numbers than did the other study areas. This was due to the presence of grassland species (prairie kingsnake, speckled kingsnake, eastern coachwhip, western ribbon snake). This shows that snakes responded to radical changes in vegetation structure by changes in species composition but not changes in numbers of individuals.

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BIRD AND SMALL MAMMAL COMMUNITIES OF LOBLOLLY-SHORTLEAF PINE STANDS IN EAST TEXAS

R. Montague Whiting, Jr. and Robert R. Fleet

Abstract.--Species compositions and relative abundances of birds and mammals were investigated on 16 study areas in the Angelina National Forest in San Augustine County, near Broaddus, Texas. Four study areas were established in pine stands of each of the following tree sizes: seedling, sapling, pole, sawtimber. Generally, the highest numbers of species and individuals of birds and small mammals were found in seedling study areas. Numbers of birds and mammals generally decreased as stand age and thus tree size increased. A drought after the 1st sample year adversely affected both birds and small mammals. As bird data were collected only during the 1st year following the drought, no trends could be developed. However, small mammals were censused 2 years thereafter, and several trends were evident. Cotton rat populations crash immediately following the drought, but rebounded strongly the following year. Excluding eastern woodrats, populations of the remaining small rodents also crashed after the drought, and did not recover in 2 years. Numbers of woodrats declined in the trapping period immediately following the drought, but had recovered by the following trapping period.

INTRODUCTION

In 1978, the Chief of the U.S. Forest Service approved the Southern Evaluation Project. The project was designed to study biological, physical, economic and social attributes as affected by timber, range and wildlife management in the southern United States (Pearson 1981). This study, which was a part of the Southern Evaluation Project, was designed to describe the species compositions and relative abundances of birds and mammals in seedling, sapling, pole and sawtimber tree size class stands in East Texas.

STUDY AREAS

Study areas were selected from a contiguous tract of approximately 8000 acres (3200 ha) in the pine-hardwood forest of the Angelina National Forest in San Augustine County, east of the Attoyac arm of Sam Rayburn Reservoir. Four study sites, each approximately 2000 acres (800 ha) were used. Within or adjacent to each study site, 4 evenage pine stand study areas, classified by tree size as seedling, sapling, pole or sawtimber, were selected. The 16 study areas varied somewhat in size, but all were large enough to permit establishment of strip transects totaling 22.5 acres (9 ha) with appropriate buffers. Study areas were selected on the basis of homogeneity of soils and overstory vegetation. Soils of the study areas included the Cuthbert, Lacerda, Renzel, Tenaha and Woodtell series (Dolezel and Holt 1979). Detailed descriptions of each study area may be found in Whiting and Fleet (1985). The study areas were numbered as follows: seedling 1, 5, 9, 13; sapling 2, 6, 10, 14; pole 3, 7, 11, 15; and sawtimber 4, 8, 12, 16.

METHODS

All taxa were monitored using transects 984 ft (300 m) long. Each study area had 3 such transects, thus 3 replications per study area. Transects were parallel in cardinal directions, at least 328 ft (100 m) apart, and no closer than 246 ft (75 m) to a different vegetation type. To facilitate travel, transect lines were cleared of brush as needed. Perpendicular distances were marked at 164 ft intervals along each transect line (Whiting et al. 1983).

Vegetation

Vegetation of each study site was extensively inventoried by other scientists

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(Smeins and Hinton 1981). However, in order to characterize the study areas, some vegetation data were collected during summer 1980 and winter 1981. Sampling methods for vegetation are detailed in Whiting et al. (1983) and Whiting and Fleet (1985).

Birds

Birds were censused during the winter (January-February) and spring (May-June) seasons of 1980 and 1981. The same 4 census-takers were used throughout a season. Birds were censused only on days when all census-takers could work. Each census-taker sampled 2 study areas per census-day. On successive census-days, census-takers sampled different study areas until each had sampled all 16 study areas twice; this provided a total of 8 censuses per study area and 128 per season. The 1st sample order was reversed the 2nd time a given census-taker sampled the same pair of study areas. Birds seen or heard within 164 ft (50 m) of the transect line were recorded. Information recorded included observer name, Julian date, starting and ending time of the census, stand number, and stand age. For each bird observation, data recorded included American Ornithological Union (AOU) number, number of individuals, sex, observer-to-bird distance, and coordinates of the bird. If a bird was heard but not seen, the number of individuals was coded as 1 and sex as unknown. (Whiting and Fleet 1985).

Small Mammals

Population densities of small mammals, primarily rodents, were evaluated using standard capture-recapture techniques (Overton 1971). Trapping seasons were set to coincide with winter and spring bird sampling seasons. However, small mammals were trapped for 3 consecutive years (1980-1982).

To capture small mammals, 16 Sherman live traps were spaced at 66 ft (20 m) intervals along each transect, thus 48 traps per study area. Traps were baited daily with a 50:50 mixture of chicken scratch and rolled oats and checked each morning for 14 consecutive days. This provided 672 trap-days per study area per season.

The 1st time a mammal was captured, a single toe was clipped on a specific foot. Age (adult, juvenile) and sex (male, female, unknown, pregnant/lactating) of the animal were noted prior to release at the point of capture. Other data recorded included observer name, Julian date, stand number and age, transect and trap number, species code, whether the animal was a recapture or not, and if it was alive or dead.

Squirrels

Tree squirrel numbers were estimated using time-area and nest counts (Goodrum 1961). The 4 sampling periods used when estimating squirrel numbers were early fall in 1979 and 1980 and early spring in 1980 and 1981. Squirrel censuses were completed before the hunting season opened. During each sampling period, 4 2-hour time-area counts were made along the transect lines of eac pole and sawtimber study area. For each study area and sampling period, 2 counts were made early in the morning and 2 in the afternoon. Th observer-to-squirrel distance for each squirrel seen was recorded. Estimated densities were the calculated (Goodrum 1961).

Squirrel nests were counted during February of 1980 and 1981. On each pole and sawtimber stand, 4 observers independently counted the number of active nests within 164 ft of either side of the transect. For each stand, the average number of nests per acre was determined.

Large and Mid-sized Mammals

Mammals too large to be captured in live traps were counted at night during fall 1979 and 1980 and spring 1980 and 1981. Using a spotlight, an observer slowly walked each transect and recorded, by species, the numbers o animals seen or heard. Spotlight counts generally started about an hour after sunset and took about 45 minutes per study area. Also, during the bird and small mammal censuses, incidental mammals observed were recorded.

Statistical Analyses

Diversity index values were computed using Shannon's (1948) measure of information (species diversity); equitability, or "evenness" values were computed using Pielou's (1966) method. Whe comparing vegetational, avian and small mammal data, nonparametric tests were used. Comparison were made between study areas of the same tree size class; none were made between study areas o different tree size classes. Generally, Kruskel-Wallis one-way analysis of variance by ranks (Nie and Hull 1981) and multiple compariso tests (Daniel 1978) were used. The null hypothesis of no difference between groups being tested was used throughout, as was the 0.05 leve of significance.

RESULTS AND DISCUSSION

There was a general drying trend during 1979-1981 (Rakowitz 1983). The summer of 1980 was the hottest and driest recorded during the 1965-1984 period. The eastern half of Texas was subjected to a severe heat wave and an associate drought from mid-June to mid-September. Virtually all temperature and moisture parameter reflected the extreme conditions during that summer (Whiting and Fleet 1985). The climatic extremes had drastic impacts on avian and small mammal communities. Heat and lack of moisture adversely affected the plant communities also.

As the treatment block and study sites were established before this project was initiated, "classic" seedling, sapling, pole and sawtimber stands (Stoddart 1959, Young 1982) were not available within each study site. As a result, there was overlap of some parameters between study areas of different tree size classes. However, we believe that the 4 stands chosen for each size class were representative (Table 1).

Table 1. Stand ages and structural characteristics of large vegetation (> 4.0 inches dbh) as tallied on 18 1/10 acre plots (= 1.8 acres) on each study area during summer 1980. Average dbh and height values for stands 1 & 5 are for residual overstory trees. Average height of the pine and hardwood seedlings (grouped) are shown in parentheses.

Study area no.	Tree size class	Average dbh (inches) Pine	Hdwd	Combined	Average height (feet) Pine	Hdwd	Combined	Average age (pines)
1	Seedling	7.3[a]	6.9	7.0[a]	55.4[a]	39.4	43.0 (5.9)[a]	*ca* 3.5
5	Seedling	4.7	5.5	5.4	50.0	35.1	36.4 (5.2)	*ca* 2.5
9	Seedling	-	-	-	-	-	- (2.3)	0.5
13	Seedling	-	-	-	-	-	- (5.9)	*ca* 3.5
2	Sapling	4.8	4.8	4.8	28.9	29.5	28.9	7.5
6	Sapling	5.6	5.4	5.6	34.4	29.2	34.4	13.5
10	Sapling	5.3	5.8	5.3	31.2	30.1	31.2	12.5
14	Sapling	5.4	5.7	5.5	35.4	34.8	35.4	9.5
3	Pole	8.4[a]	7.0	7.9	60.0	44.9	54.1	36.5[c]
7	Pole	10.8	6.6	9.6	64.9	43.6	59.0	40.7
11	Pole	8.9	6.1	7.9	63.0	44.9	56.4	50.2
15	Pole	10.8	6.5	9.0	67.2	44.0	57.7	38.4[b]
4	Sawtimber	12.1	7.9	9.5	80.0	60.0	67.6	57.0
8	Sawtimber	9.9	6.4	8.5	68.2	47.9	60.0	59.7
12	Sawtimber	11.1	6.0	8.5	67.9	44.6	56.1	53.4
16	Sawtimber	11.7	6.7	9.5	74.5	47.2	62.3	45.3[b]

[a] Indicates a significant difference, at the 0.05 level, between diameters or heights in stands of the same tree size class (Kruskal - Wallis test). Hardwoods were not tested.

[b] Indicates a significant difference, at the 0.05 level, between lines within the specific study area (Kruskal - Wallis test).

[c] Duncan's Multiple Range tests grouped ages of the pole and sawtimber stands as follow (youngest to oldest): Study area numbers 3 & 15; 15 & 7; 7 & 16; 16 & 11; 11 & 12; and 12, 4 & 8. However, a paired t-test showed that the pines on the sawtimber study areas were significantly ($P \leq 0.05$) older than those on the pole areas.

Characteristics of the vegetation of the study areas are discussed in detail in Whiting and Fleet (1985).

BIRDS

A total of 13,358 birds representing 115 species were recorded while making 512 censuses during the 2 year study period (Table 2). In a similar study, Whiting (1978) recorded 13 species that we did not, and we recorded 17 that he did not.

Differences Between Years

There were notable differences in numbers of species and individuals recorded between years. For winter censuses, numbers of individuals declined drastically from 1980 to 1981. Declines were 40, 52, 24, and 23% for the seedling, sapling, pole and sawtimber study areas, respectively. Also, there were slight declines in numbers of species (Table 2); these declines can be attributed to the drought.

The larger declines occurred on the younger age study areas; probably the plants in the seedling and sapling study areas were more susceptible to the drought than were those of the pole and sawtimber study areas. Ground foraging species such as bobwhites, common flickers, eastern meadowlarks, white-throated sparrows, chipping sparrows and slate-colored juncos were recorded in reduced numbers in 1981. Other species recorded in reduced numbers in 1981 included cedar waxwings, yellow-rumped warblers and robins (Table 2).

For spring censuses, more birds were recorded in 1981 than in 1980 (Table 2). Numbers of individuals increased in all stands and numbers of species increased in all but the sawtimber stands. Reasons for these increases after the drought are unclear. Spring censuses started after 30 April in both years, well after the vegetation had resumed growth. More vegetative material may have been produced in the spring after the drought (1981) and thus increased both feeding and nesting sites for a variety of birds.

Table 2. Numbers of individual birds recorded by tree size class study area, species and season (W = winter, S = spring, C = combined) for each year, with study area and seasonal totals and totals for the whole study period.

AOU no.	Common name Scientific name		Study area												Yearly and seasonal totals			Study total
			Seedling			Sapling			Pole			Sawtimber						
			1980	1981	Total	1980	1981	Total	1980	1981	Total	1980	1981	Total	1980	1981	Total	
144	Wood Duck	W	4	–	4	–	–	–	–	–	–	–	–	–	4	–	4	
	Aix sponsa	S	1	–	1	–	–	–	–	–	–	–	–	–	1	–	1	5
201	Green-backed Heron	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Butorides striatus	S	1	–	1	–	–	–	–	–	–	–	–	–	1	–	1	1
228	American Woodcock	W	8	7	15	1	1	2	1	1	2	–	–	–	10	9	19	
	Scolopax minor	S	–	1	1	–	–	–	–	–	–	–	–	–	–	1	1	20
289	Northern Bobwhite	W	62	10	72	30	10	40	–	–	–	10	–	10	102	20	122	
	Colinus virginianus	S	30	13	43	3	5	8	4	1	5	5	–	5	42	19	61	183
316	Mourning Dove	W	31	105	136	–	–	–	–	–	–	–	–	–	31	105	136	
	Zenaida macroura	S	17	10	27	4	4	8	4	1	5	3	6	9	28	21	49	185
325	Turkey Vulture	W	–	11	11	–	–	–	–	–	–	4	1	5	4	12	16	
	Cathartes aura	S	2	1	3	–	–	–	–	–	–	–	–	–	2	1	3	19
326	Black Vulture	W	–	–	–	–	–	–	–	2	2	–	–	–	–	2	2	
	Coragyps atratus	S	1	–	1	–	–	–	–	–	–	–	–	–	1	–	1	3
332	Sharp-shinned Hawk	W	–	–	–	–	–	–	–	–	–	–	4	4	–	4	4	
	Accipiter striatus	S	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	4
333	Cooper's Hawk	W	–	–	–	–	–	–	–	–	–	1	–	1	1	–	1	
	Accipiter cooperii	S	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
337	Red-tailed Hawk	W	3	2	5	–	–	–	–	–	–	–	–	–	3	2	5	
	Buteo jamaicensis	S	1	–	1	–	–	–	–	–	–	–	–	–	1	–	1	6
339	Red-shouldered Hawk	W	–	–	–	–	2	2	–	1	1	–	–	–	–	3	3	
	Buteo lineatus	S	–	–	–	–	–	–	–	–	–	–	1	1	–	1	1	4
343	Broad-winged Hawk	W	–	–	–	1	–	1	–	–	–	–	–	–	1	–	1	
	Buteo platypterus	S	–	–	–	–	–	–	1	1	2	–	–	–	1	1	2	3
360	American Kestral	W	2	1	3	1	–	1	–	–	–	–	–	–	3	1	4	
	Falco sparverius	S	1	–	1	–	–	–	–	–	–	–	–	–	1	–	1	5
368	Barred Owl	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Strix varia	S	–	–	–	–	–	–	–	–	–	1	–	1	1	–	1	1
375	Great Horned Owl	W	–	–	–	–	–	–	–	–	–	1	–	1	1	–	1	
	Bubo virginianus	S	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	1
385	Greater Roadrunner	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Geococcyx californianus	S	–	–	–	–	1	1	–	–	–	–	–	–	–	1	1	1
387	Yellow-billed Cuckoo	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Coccyzus americanus	S	2	9	11	10	6	16	1	1	2	4	5	9	17	21	38	38
388	Black-billed Cuckoo	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Coccyzus erythropthalmus	S	–	–	–	–	–	–	–	–	–	–	1	1	–	1	1	1
393	Hairy Woodpecker	W	5	10	15	1	1	2	4	–	4	3	3	6	13	14	27	
	Picoides villosus	S	2	3	5	2	1	3	1	4	5	–	–	–	5	8	13	40
394	Downy Woodpecker	W	8	11	19	3	2	5	5	5	10	6	8	14	22	26	48	
	Picoides pubescens	S	2	5	7	–	2	2	–	1	1	4	1	5	6	9	15	63
402	Yellow-bellied Sapsucker	W	7	6	13	2	3	5	9	6	15	13	31	44	31	46	77	
	Sphyrapicus varius	S	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	77
405	Pileated Woodpecker	W	4	9	13	2	–	2	5	3	8	18	17	35	29	29	58	
	Dryocopus pileatus	S	6	1	7	1	1	2	4	3	7	7	6	13	18	11	29	87
406	Red-headed Woodpecker	W	17	–	17	–	–	–	–	–	–	–	1	1	17	1	18	
	Melanerpes erythrocephalus	S	39	20	59	2	–	2	3	5	8	–	1	1	44	26	70	88
409	Red-bellied Woodpecker	W	11	19	30	3	1	4	8	15	23	23	16	39	45	51	96	
	Melanerpes carolinus	S	11	17	28	3	–	3	7	7	14	11	15	26	32	39	71	167
412	Northern Flicker	W	27	5	32	15	5	20	1	–	1	5	2	7	48	12	60	
	Colaptes auratus	S	1	–	1	–	–	–	–	–	–	–	–	–	1	–	1	61
416	Chuck-will's-widow	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Caprimulgus carolinensis	S	–	–	–	1	–	1	1	1	2	1	3	4	3	4	7	7
423	Chimney Swift	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Chaetura pelagica	S	5	–	5	–	–	–	–	–	–	–	–	–	5	–	5	5
428	Ruby-throated Hummingbird	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Archilochus colubris	S	4	15	19	–	1	1	–	–	–	–	–	–	4	16	20	20
444	Eastern Kingbird	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Tyrannus tyrannus	S	10	5	15	–	–	–	–	–	–	–	–	–	10	5	15	15
452	Great Crested Flycatcher	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Myiarchus crinitus	S	32	22	54	6	10	16	4	3	7	16	15	31	58	50	108	108

Continued on next page.

ble 2. Continued.

			Study area															
OU	Common name		Seedling			Sapling			Pole			Sawtimber			Yearly and seasonal totals			Study
.	Scientific name		1980	1981	Total	1980	1981	Total	1980	1981	Total	1980	1981	Total	1980	1981	Total	total
56	Eastern Phoebe	W	2	1	3	3	1	4	1	2	3	2	–	2	8	4	12	
	Sayornis phoebe	S	–	–	–	–	–	–	–	–	–	3	–	3	3	–	3	15
61	Eastern Wood-pewee	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Contopus virens	S	5	2	7	1	–	1	1	3	4	6	9	15	13	14	27	27
65	Acadian Flycatcher	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Empidonax virescens	S	1	–	1	–	–	–	1	2	3	16	23	39	18	25	43	43
77	Blue Jay	W	26	25	51	34	51	85	18	15	33	38	27	65	116	118	243	
	Cyanocitta cristata	S	32	9	41	26	28	54	14	18	32	27	24	51	99	79	178	412
88	American Crow	W	26	12	38	6	14	20	7	15	22	17	1	18	56	42	98	
	Corvus brachyrhynchos	S	1	1	2	8	1	9	4	1	5	7	2	9	20	5	25	123
95	Brown-headed Cowbird	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Molthrus ater	S	67	63	130	17	5	22	16	4	20	16	9	25	116	81	197	197
01	Eastern Meadowlark	W	63	33	96	–	–	–	–	–	–	–	–	–	63	33	96	
	Sturnella magna	S	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	96
06	Orchard Oriole	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Icterus spurius	S	2	2	4	–	–	–	–	1	1	–	–	–	2	3	5	5
07	Northern Oriole	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Icterus galbula	S	1	6	7	–	4	4	–	–	–	–	–	–	1	10	11	11
11	Common Grackle	W	–	–	–	79	–	79	–	–	–	–	–	–	79	–	79	
	Quiscalus quiscula	S	3	–	3	–	–	–	–	–	–	–	–	–	3	–	3	82
17	Purple Finch	W	–	25	25	–	4	4	–	2	2	–	–	–	–	31	31	
	Carpodacus purpureus	S	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	31
29	American Goldfinch	W	7	36	43	–	–	–	–	5	5	–	–	–	7	41	48	
	Carduelis tristis	S	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	48
33	Pine Siskin	W	–	21	21	–	–	–	–	–	–	–	–	–	–	21	21	
	Carduelis pinus	S	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	21
40	Vesper Sparrow	W	8	–	8	–	–	–	–	–	–	–	–	–	8	–	8	
	Pooecetes gramineus	S	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	8
42	Savannah Sparrow	W	20	1	21	–	–	–	–	–	–	–	–	–	20	1	21	
	Passerculus sandwichensis	S	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	21
46	Grasshopper Sparrow	W	1	2	3	–	–	–	–	–	–	–	–	–	1	2	3	
	Ammodramus savannarum	S	1	–	1	–	–	–	–	–	–	–	–	–	1	–	1	4
54	White-crowned Sparrow	W	–	–	–	3	–	3	–	–	–	–	–	–	3	–	3	
	Zonotrichia leucophrys	S	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
58	White-throated Sparrow	W	191	125	316	36	31	67	1	53	54	1	19	20	229	228	457	
	Zonotrichia albicollis	S	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	457
60	Chipping Sparrow	W	69	–	69	3	–	3	–	–	–	–	–	–	72	–	72	
	Spizella passerina	S	–	–	–	–	–	–	1	–	1	2	1	3	3	1	4	76
63	Field Sparrow	W	–	–	–	–	2	2	–	–	–	–	–	–	–	2	2	
	Spizella pusilla	S	3	–	3	–	–	–	–	–	–	–	–	–	3	–	3	5
67	Dark-eyed Junco	W	345	110	455	1	16	17	–	9	9	–	24	24	346	159	505	
	Junco hyemalis	S	–	–	–	–	–	–	–	1	1	–	–	–	–	1	1	506
575	Bachman's Sparrow	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Aimophila aestivalis	S	12	2	14	–	–	–	–	–	–	–	–	–	12	2	14	14
581	Song Sparrow	W	10	6	16	–	–	–	–	–	–	–	1	1	10	7	17	
	Melospiza melodia	S	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	17
583	Lincoln's Sparrow	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Melospiza lincolnii	S	–	11	11	–	–	–	–	–	–	–	–	–	–	11	11	11
584	Swamp Sparrow	W	6	–	6	–	–	–	–	–	–	–	–	–	6	–	6	
	Melospiza georgiana	S	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	6
585	Fox Sparrow	W	–	2	2	1	–	1	–	–	–	–	–	–	1	2	3	
	Passerella iliaca	S	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	3
587	Rufous-sided Towhee	W	28	9	37	5	5	10	–	–	–	–	–	–	33	14	47	
	Pipilo erythrophthalmus	S	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	47
593	Northern Cardinal	W	83	82	165	87	86	173	67	60	127	43	49	92	280	277	557	
	Cardinalis cardinalis	S	85	127	212	115	151	266	95	92	187	84	84	168	379	454	833	1390
595	Rose-breasted Grosbeak	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Pheucticus ludovicianus	S	–	3	3	–	–	–	–	–	–	–	2	2	–	5	5	5
597	Blue Grosbeck	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Guiraca caerulea	S	11	15	26	1	–	1	–	–	–	–	–	–	12	15	27	27

Continued on next page.

Table 2. Continued.

AOU no.	Common name Scientific name		Study area Seedling 1980	1981	Total	Sapling 1980	1981	Total	Pole 1980	1981	Total	Sawtimber 1980	1981	Total	Yearly and seasonal totals 1980	1981	Total	St to
598	Indigo Bunting	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Passerina cyanea	S	134	188	322	5	7	12	–	–	–	3	–	3	142	195	337	3
601	Painted Bunting	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Passerina ciris	S	–	2	2	–	3	3	–	–	–	–	–	–	–	5	5	
604	Dickcissel	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Spiza americana	S	1	–	1	–	–	–	–	–	–	–	–	–	1	–	1	
608	Scarlet Tanager	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Piranga olivacea	S	–	–	–	–	–	–	–	1	1	–	–	–	–	1	1	
610	Summer Tanager	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Piranga rubra	S	23	47	70	19	11	30	32	24	56	35	44	79	109	126	235	2
611	Purple Martin	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Progne subis	S	1	3	4	–	–	–	–	–	–	–	–	–	1	3	4	
613	Barn Swallow	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Hirundo rustica	S	–	1	1	–	–	–	–	–	–	–	–	–	–	1	1	
614	Tree Swallow	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Tachycineta bicolor	S	5	–	5	–	–	–	–	–	–	–	–	–	5	–	5	
619	Cedar Waxwing	W	20	–	20	–	–	–	8	–	8	2	–	2	30	–	30	
	Bombycilla cedrorum	S	–	6	6	–	–	–	–	3	3	–	–	–	–	9	9	
622	Loggerhead Shrike	W	2	1	3	–	–	–	1	–	1	–	–	–	3	1	4	
	Lanius ludovicianus	S	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
624	Red-eyed Vireo	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Vireo olivaceus	S	11	32	43	24	28	52	60	71	131	87	113	200	182	244	426	42
626	Philadelphia Vireo	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Vireo philadelphicus	S	–	–	–	–	–	–	–	1	1	–	–	–	–	1	1	
627	Warbling Vireo	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Vireo gilvus	S	–	–	–	–	–	–	–	–	–	–	1	1	–	1	1	
628	Yellow-throated Vireo	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Vireo flavifrons	S	2	1	3	2	–	2	3	3	6	4	3	7	11	7	18	1
629	Solitary Vireo	W	–	–	–	1	–	1	–	2	2	–	–	–	1	2	3	
	Vireo solitarius	S	–	–	–	–	1	1	–	–	–	–	–	–	–	1	1	
631	White-eyed Vireo	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Vireo griseus	S	57	71	128	52	89	141	–	–	–	2	–	2	111	160	271	27
636	Black-and-white Warbler	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Mniotilta varia	S	5	10	15	30	58	88	12	20	32	12	19	31	59	107	166	16
638	Swainson's Warbler	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Limnothlypis swainsonii	S	–	–	–	–	–	–	–	–	–	1	-	1	1	–	1	
639	Worm-eating Warbler	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Helmitheros vermivorus	S	–	3	3	23	12	35	6	6	12	3	–	3	32	21	53	5
647	Tennessee Warbler	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Vermivora peregrina	S	–	1	1	–	–	–	–	–	–	–	–	–	–	1	1	
648	Northern Parula	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Parula americana	S	18	6	24	2	–	2	–	–	–	–	–	–	20	6	26	2
655	Yellow-rumped Warbler	W	39	18	57	68	27	95	74	37	111	87	60	147	268	142	410	
	Dendroica coronata	S	1	–	1	–	–	–	–	–	–	–	–	–	1	–	1	41
657	Magnolia Warbler	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Dendroica magnolia	S	–	1	1	–	–	–	–	–	–	–	–	–	–	1	1	
658	Cerulean Warbler	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Dendroica cerulea	S	–	–	–	–	2	2	–	–	–	–	–	–	–	2	2	
660	Bay-breasted Warbler	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Dendroica castanea	S	–	–	–	–	6	6	–	–	–	–	–	–	–	6	6	
663	Yellow-throated Warbler	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Dendroica dominica	S	–	2	2	8	3	11	–	–	–	1	1	2	9	6	15	1
667	Black-throated Green War.	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Dendroica virens	S	–	2	2	–	3	3	–	–	–	–	–	–	–	5	5	
671	Pine Warbler	W	6	18	24	26	26	52	209	138	347	150	103	253	391	285	676	
	Dendroica pinus	S	3	2	5	9	19	28	79	120	199	71	109	180	162	250	412	108
673	Prairie Warbler	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Dendroica discolor	S	19	34	53	1	1	2	–	–	–	–	–	–	20	35	55	5
674	Ovenbird	W	–	–	–	–	–	–	–	–	–	–	–	–	–	–	–	
	Seiurus aurocapillus	S	–	–	–	–	1	1	–	–	–	–	–	–	–	1	1	

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able 2. Continued.

			Study area															
			Seedling			Sapling			Pole			Sawtimber			Yearly and seasonal totals			
OU o.	Common name Scientific name		1980	1981	Total	1980	1981	Total	1980	1981	Total	1980	1981	Total	1980	1981	Total	Study total
76	Louisiana Waterthrush	W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Seiurus motacilla	S	-	-	-	-	-	-	-	1	1	-	2	2	-	3	3	3
77	Kentucky Warbler	W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Oporornis formosus	S	7	26	33	38	36	74	7	2	9	1	2	3	53	66	119	119
81	Common Yellowthroat	W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Geothlypis trichas	S	23	37	60	6	1	7	1	-	1	-	-	-	30	38	68	68
83	Yellow-breasted Chat	W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Icteria virens	S	133	172	305	53	24	77	-	-	-	1	-	1	187	196	383	383
84	Hooded Warbler	W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Wilsonia citrina	S	6	2	8	27	28	55	41	47	88	35	34	69	109	111	220	220
87	American Redstart	W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Setophaga ruticilla	S	-	1	1	-	-	-	-	-	-	-	-	-	-	1	1	1
04	Gray Catbird	W	-	-	-	-	1	1	-	-	-	-	-	-	-	1	1	
	Dumetella carolinensis	S	-	17	17	-	2	2	-	-	-	-	-	-	-	19	19	20
05	Brown Thrasher	W	6	3	9	25	12	37	-	2	2	1	-	1	32	17	49	
	Toxostoma rufum	S	-	-	-	1	1	2	1	-	1	-	-	-	2	1	3	52
18	Carolina Wren	W	90	60	150	33	35	68	62	55	117	49	76	125	234	226	460	
	Thryothorus ludovicianus	S	51	35	86	38	37	75	77	42	119	56	34	90	222	148	370	830
21	House Wren	W	-	-	-	-	1	1	-	-	-	-	1	1	-	2	2	
	Troglodytes aedon	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2
22	Winter Wren	W	2	-	2	-	-	-	2	-	2	-	1	1	4	1	5	
	Troglodytes troglodytes	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	5
26	Brown Creeper	W	-	3	3	-	-	-	4	16	20	2	13	15	6	32	38	
	Certhia americana	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	38
27	White-breasted Nuthatch	W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Sitta carolinensis	S	-	4	4	-	-	-	-	-	-	-	2	2	-	6	6	6
29	Brown-headed Nuthatch	W	12	12	24	2	-	2	4	7	11	7	15	22	25	34	59	
	Sitta pusilla	S	7	17	24	1	-	1	7	10	17	12	18	30	27	45	72	131
31	Tufted Titmouse	W	27	33	60	13	24	37	68	56	124	43	31	74	151	144	295	
	Parus bicolor	S	28	41	69	31	40	71	39	69	108	81	70	151	179	220	399	694
736	Carolina Chickadee	W	72	61	133	46	29	75	80	111	191	82	95	177	280	296	576	
	Parus carolinensis	S	41	59	100	54	40	94	42	86	128	41	45	86	178	230	408	984
748	Golden-crowned Kinglet	W	-	8	8	20	27	47	81	56	137	26	28	54	127	119	246	
	Regulus satrapa	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	246
749	Ruby-crowned Kinglet	W	39	27	66	91	13	104	117	38	155	134	16	150	381	94	475	
	Regulus calendula	S	-	1	1	-	1	1	-	-	-	-	-	-	-	2	2	477
751	Blue-gray Gnatcatcher	W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Polioptila caerulea	S	28	40	68	4	3	7	6	1	7	5	2	7	43	46	89	89
755	Wood Thrush	W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Hylocichla mustelina	S	-	-	-	-	-	-	8	-	8	29	8	37	37	8	45	45
757	Gray-cheeked Thrush	W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Catharus minimus	S	-	-	-	-	-	-	-	1	1	-	-	-	-	1	1	1
758	Swainson's Thrush	W	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	
	Catharus ustulatus	S	-	-	-	-	1	1	-	1	1	-	-	-	-	2	2	2
759	Hermit Thrush	W	11	21	32	39	23	62	15	14	29	12	8	20	77	66	143	
	Catharus guttatus	S	-	-	-	-	-	-	-	-	-	-	1	1	-	1	1	144
761	American Robin	W	192	8	200	274	3	277	105	3	108	67	1	68	638	15	653	
	Turdus migratorius	S	-	-	-	-	-	-	3	-	3	-	-	-	3	-	3	656
766	Eastern Bluebird	W	20	5	25	1	-	1	2	-	2	-	-	-	23	5	28	
	Sialia sialis	S	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	28
	Total species	W	42	41	48	34	29	39	27	28	34	28	28	34	52	50	60	
		S	54	55	69	36	41	49	34	38	43	36	36	44	65	76	93	
		C	75	79	93	57	57	71	49	54	61	51	51	63	89	102	115	
	Total individuals	W	1612	964	2576	956	456	1412	959	729	1688	847	652	1499	4374	2801	7175	
		S	996	1227	2223	628	678	1306	586	659	1245	693	716	1409	2903	3280	6183	
		C	2608	2191	4799	1584	1134	2718	1545	1388	2933	1540	1368	2908	7277	6081	13358	

Differences Between Tree Size Class Study Areas

Winter.--During winter surveys, more bird species and individuals were recorded in the seedling study areas than in the other study areas (Table 2). These results are similar to those of other studies (Whiting 1978, Baggett 1983) for the same reasons: more flocking granivorous birds in the seedling stands than on the other stands. Dickson and Segelquist (1977) recorded greater winter bird densities in young sapling study areas which were described as having characteristics intermediate between our seedling and sapling study areas. This suggests that high numbers of winter birds characteristic of pine seedling stands may be maintained into the young sapling stage.

Trends in numbers of species were similar between years (Fig. 1). These trends seem to be intermediate between those found by Dickson and Segelquist (1977), which showed a flattened line, and by Whiting (1978), which showed a U-shaped curve. Trends in numbers of individuals differed somewhat between study years (Fig. 1). This was a result of reduced numbers of birds tallied in the seedling and sapling study areas during the winter 1981 censuses. These trends were similar to those found by Dickson and Segelquist (1977), but differed from those found by Whiting (1978).

Spring.--During both spring surveys, more species and individuals were recorded on the seedling study areas than on other study areas (Table 2). These results are somewhat different from those of other researchers working in similar areas (Whiting 1978, Dickson and Segelquist 1979, Baggett 1983). Generally, numbers of species and individuals that we recorded in seedling stands were higher in relation to the other stands than was the case in other studies. This can be attributed to the fact that 3 of our seedling study areas were naturally seeded southern pine beetle salvage areas rather than site prepared, planted stands. The naturally seeded study ar were structurally and functionally more divers than the planted study area (Whiting and Fleet 1985).

Trends in numbers of species and individua between tree size class stands for our spring (Fig. 2) are very similar to trends for our wi data (Fig. 1). However, trends in our spring are dissimilar to those found by other research (Whiting 1978, Dickson and Segelquist 1979). T likewise can be attributed to the fact that sta structures of our study areas were different fr the structures described by other researchers.

Differences Among Tree Size Class Study Areas

Seedling study areas.--During winter 1980, differences in the numbers of individuals recor among the seedling study areas were significant Over twice as many birds were recorded on the planted seedling stand (study area 9) as on any the other seedling stands (Table 3). However, of the birds recorded on the planted study area were juncos and robins. When eastern meadowlar and chipping sparrows are included, these 4 species comprised 76.5% of all birds recorded. During winter 1981, differences in numbers of individuals recorded among the 4 seedling study areas were not significant (Table 3); however, differences in numbers of species were. Juncos robins and chipping sparrows were virtually abs from the planted seedling study area; bird numb were dominated by doves and meadowlarks, which comprised 77% of all birds tallied there. The number of species recorded on that stand was significantly lower than the numbers recorded o the other stands (Whiting and Fleet 1985). Whe data for both winters were combined and tested among stands, differences in numbers of individuals were not significant (Table 3). The high numbers for planted study area in 1980 were offset by the low numbers in 1981.

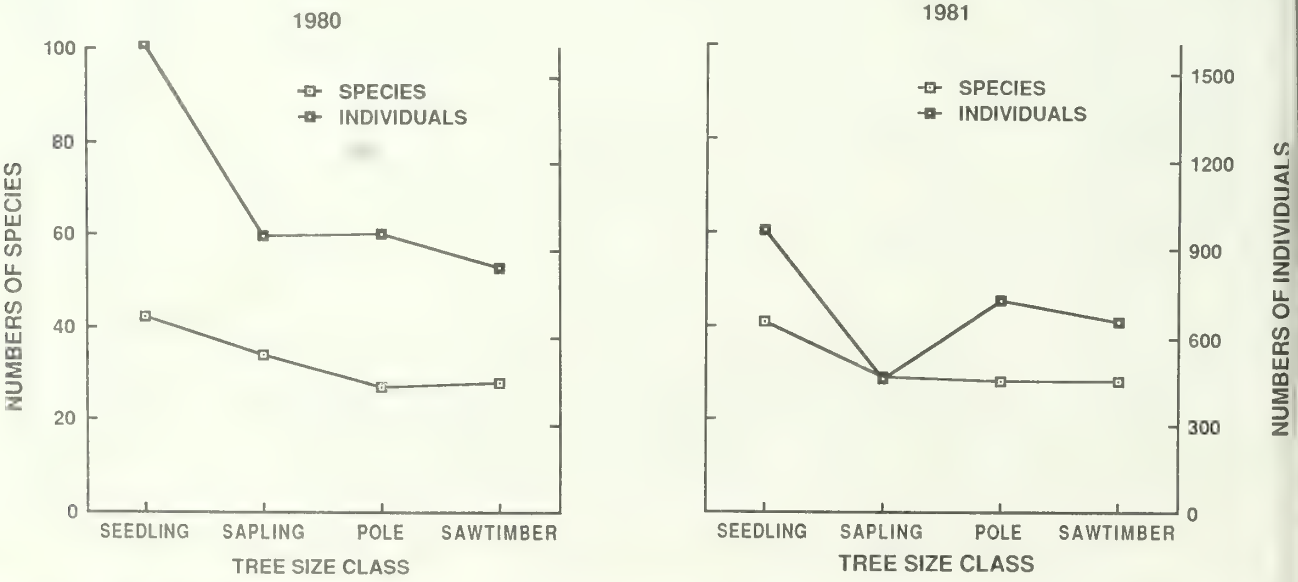


Figure 1. Total numbers of bird species and individuals recorded on the seedling, sapling, pole and sawtimber study areas during the winters of 1980 and 1981.

Table 3. Total numbers of species and individual birds and average species diversity (H') and equitability (J) values by study area number, year and season. Stands are grouped by tree size class.

Tree size/ Parameter	Study area number 1980: 1	5	9	13	1981: 1	5	9	13
SEEDLING								
Winter								
Total species	24	25	19	32	28	31	14	26^{a,b}
Total individ.	243	351	732	286^{a}	265	347	168	184
H'	2.060	1.999	1.446	1.905^{a}	2.153	1.901	0.621	1.863^{a,b}
J	0.896	0.887	0.712	0.822^{a}	0.900	0.813	0.478	0.839^{a,b}
Spring								
Total species	40	25	21	26^{a,c}	42	32	17	35^{a,b,c}
Total individ.	363	228	197	208^{a}	375	329	199	324^{a,b,c}
H'	2.698	2.327	1.930	2.020^{a,c}	2.697	2.457	1.571	2.332^{a,b,c}
J	0.935	0.922	0.888	0.893^{c}	0.917	0.908	0.797	0.899^{a,b,c}
SAPLING	2	6	10	14	2	6	10	14
Winter								
Total species	21	17	22	21	19	13	22	15
Total individ.	340	181	310	125^{a}	174	102	101	79^{a,b}
H'	1.578	1.605	1.446	1.661	1.712	1.396	1.333	1.430
J	0.735	0.819	0.712	0.917	0.902	0.786	0.809	0.928^{b}
Spring								
Total species	22	25	21	27^{a}	21	24	24	22^{b}
Total individ.	184	155	115	174^{a}	190	186	137	165^{b,c}
H'	2.026	2.082	1.849	2.238^{a}	1.792	1.972	1.825	2.093^{b}
J	0.901	0.907	0.918	0.929^{c}	0.844	0.892	0.906	0.918^{a,b}
POLE	3	7	11	15	3	7	11	15
Winter								
Total species	15	20	19	22	17	22	19	17
Total individ.	157	388	246	168	152	265	174	138
H'	1.703	1.848	1.837	1.743	1.732	1.847	1.880	1.864
J	0.892	0.869	0.870	0.869	0.852	0.906	0.920	0.906
Spring								
Total species	17	25	21	21^{a}	18	21	19	21^{b}
Total individ.	135	200	121	130^{a,c}	163	213	142	141^{b,c}
H'	2.056	2.121	1.916	1.876	1.942	2.047	1.810	2.017
J	0.947	0.924	0.944	0.918	0.915	0.892	0.903	0.940
SAWTIMBER	4	8	12	16	4	8	12	16
Winter								
Total species	20	19	22	18	17	17	22	21
Total individ.	188	275	257	127	146	162	193	151
H'	1.915	1.626	1.912	1.704	1.860	1.712	1.930	1.855
J	0.905	0.874	0.880	0.917	0.930	0.889	0.865	0.880
Spring								
Total species	24	19	26	23^{c}	24	16	23	23
Total individ.	206	158	187	142	166	160	225	165
H'	2.251	1.968	2.251	2.088^{c}	1.877	1.994	2.132	2.096
J	0.939	0.920	0.938	0.932	0.886	0.924	0.921	0.928

[a] Indicates a significant difference, at the 0.05 level, between values for study areas of the same tree size class within a season (Kruskal-Wallis tests).

[b] Indicates a significant difference, at the 0.05 level, when data for the same season were combined and tested between study areas of the same tree size class (Kruskal-Wallis tests).

[c] Indicates a significant difference, at the 0.05 level, when data were combined by year and tested between study areas of the same tree size class (Kruskal-Wallis tests).

During spring 1980, the lowest numbers of species and individuals were recorded on the planted study area (Table 3). Approximately 37% more individuals were recorded on study area 1 than on any of the other seedling study areas. Woodpeckers, flycatchers and brown-headed cowbirds were common, no doubt due to the abundance and size of residual pines and hardwoods within that study area (Whiting and Fleet 1985). During spring 1981, numbers of species and individuals recorded on the planted study area were significantly lower than were numbers for the other seedling study areas. The differences were due to land management practices and the drought. The planted study area was burned and replanted between the 1980 and 1981 spring censuses. This action, coupled with previous site preparation activites, resulted in a grassy ground cover. Except for a few scattered hardwood saplings, which were heavily used by indigo buntings, nesting sites were limited to ground nesting species. When data for the spring censuses were combined, there were significant differences in all parameters (Table 3).

Yearly differences, i.e. winter and spring data combined by year then compared among study areas, were significant for numbers of species and species diversity and equitability values for 1980, and for all parameters in 1981 (Table 3). In all cases, values for the planted study area were significantly lower than those of the other stands.

Sapling study areas.--Differences in bird population parameters among the sapling study areas were not as pronounced as among seedling areas. During both winters, there were significant differences only between total numbers of individuals recorded among the sapling stands (Table 3). During winter 1981, numbers of species and individuals tallied were severely reduced from 1980. However, relationships between the stands were similar. When winter 1980 and 1981 data were combined, there were significant differences among stands in number of individuals and equitability values. Reduc abundances on study areas 6 and 14 (Table 3) w the result of high densities of pines which limited production by seed bearing plants and thus reduced food availability for wintering granivores.

During the spring 1980 censuses, significantly fewer species were recorded on study areas 2 and 10; significantly fewer individuals were recorded on study area 10 dur both springs. Reasons for the low number of species in study area 2 are unclear; low numbe of species and individuals in study area 10 resulted from the lack of woody vegetation, vines, etc. in the understory. Herbaceous plants, which furnish nesting sites for very fe species, dominated the understory (Whiting and Fleet 1985). Study area 14 was mechanically thinned between the winter and spring censuses 1980. The thinning appears to have had little impact on the bird communities, however.

Pole study areas.--There were no significa differences in numbers of species, individuals, species diversity values or equitability values among the pole stands for either winter censuse or when winter census data were combined (Table 3). Lack of differences among stands was a result of the transitory nature of winter birds inhabiting older stands which caused wide variations in the numbers of birds recorded (Noble and Hamilton 1976, Whiting 1978, Dickson and Segelquist 1979). During both spring censu periods, highest numbers of individual birds we tallied in the study area 7 which was thinned i 1979. In 1980 the differences were significant

Sawtimber study areas.--None of the comparisons made using either winter or spring data collected on the sawtimber study areas wer significant (Table 3). As with the pole stands

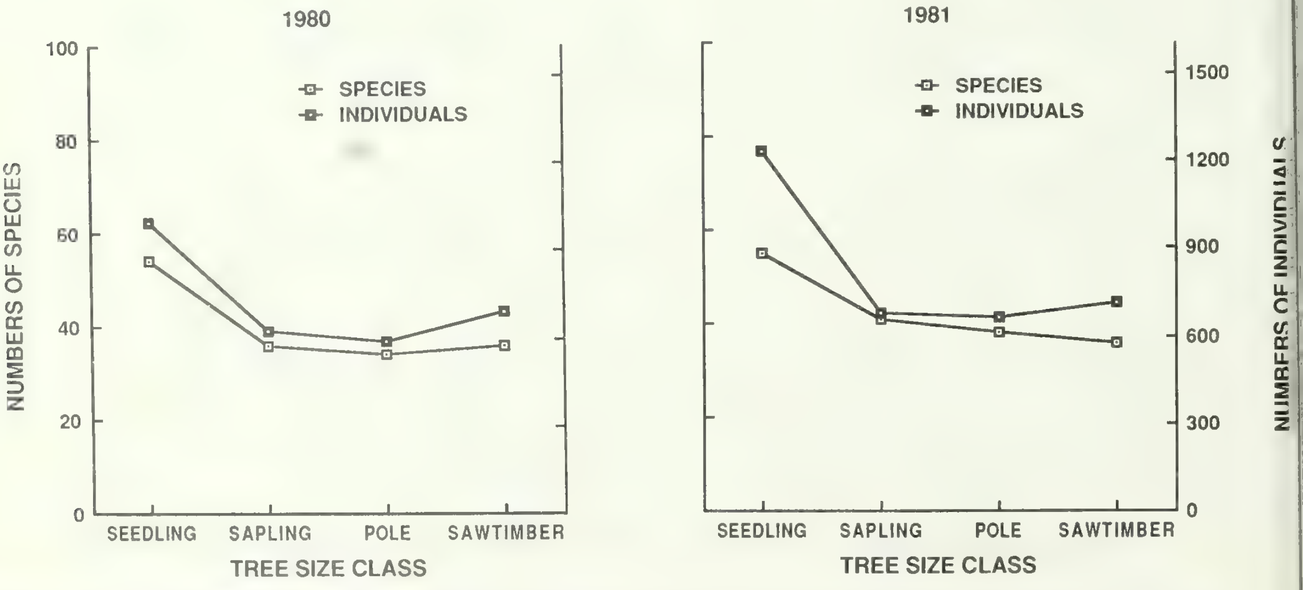


Figure 2. Total numbers of bird species and individuals recorded on the seedling, sapling, pole and sawtimber study areas during the springs of 1980 and 1981.

winter numbers varied widely among censuses. During both seasons, generally fewer species but more individuals were recorded in study areas containing higher pine components in the overstory (Whiting and Fleet 1985).

Summary.--There were differences in bird community parameters between different tree size classes. Among tree size class stands, there were also differences between seasons. We did detect significant differences between study areas among seasons. Differences among winter census periods were due to the summer drought which occurred between the study years. Throughout the study areas, numbers of winter birds declined after the drought. As stand age increased, the magnitude of the change decreased.

Numbers of birds recorded during spring census periods increased from the predrought to the postdrought censuses. As with winter birds, magnitude of the change decreased with increased stand age. These data demonstrate that birds inhabiting older stands are less affected by climatic variation than those of younger stands.

SMALL MAMMALS

During the 3 year study period, there were 6,851 small mammals recorded, including captures and recaptures (Table 4). For each of 6 study seasons, there were 10,752 trap-nights, for a total of 64,512; approximately 1 small mammal per 9.4 trap-nights was captured. Of the 13 species captured, hispid cotton rats, eastern woodrats, cotton mice, fulvous harvest mice, golden mice and rice rats were the most common, comprising approximately 43, 18, 18, 9, 8, and 3%, respectively, of the total capture.

No attempt was made to differentiate between new animals and recaptures for shorttail shrews, opossums, cottontails or flying squirrels. Shrews were too small to toe clip and the latter 3 were nontarget species. However, an opossum was definitely captured twice and a flying squirrel was captured at least 3 times. Cotton rats were the most susceptible to being recaptured (Table 5). They comprised 30.8% of the individuals captured and 43.1% of the total captures. These results are similar to those of Fleet and Dickson (1984), who recorded 36% of the individuals and 68% of the total captures as cotton rats.

Table 5. Capture-recapture characteristics of selected small mammals.

Species	No. indiv.	Total capt.	Pct. new animals
F. harvest mouse	433	596	72.7
E. harvest mouse	2	2	100.0
Cotton mouse	551	1243	44.3
Golden mouse	372	522	71.3
Rice rat	66	188	35.1
H. cotton rat	942	2952	31.9
E. woodrat	522	1255	41.6
Pine vole	4	5	80.0
House mouse	1	1	100.0
Total	3056	6601	$\bar{x}$ = 46.3

Some individuals were captured as many as 4 seasons after the initial capture (Table 6). Generally, the larger species, i.e. cotton rats and woodrats, were more likely to be recaptured after more than 1 trapping season. No doubt body size, as related to energy needs, thermoregulatory efficiency, and susceptibility to predation, was partially responsible for this

Table 4. Total numbers of individual mammals as recorded (captures and recaptures) by species and season for each year, with subtotals by season and totals for the whole study period.

		Numbers of individuals								
		Winter				Spring				
Common name	Scientific name	1980	1981	1982	Subt.	1980	1981	1982	Subt.	Total
Shorttail shrew	Blarina brevicauda	15	4	9	28	11	3	8	22	50
Fulvous harvest mouse	Reithrodontomys fulvescens	240	94	97	431	130	9	26	165	596
Eastern harvest mouse	Reithrodontomys humulis	2	0	0	2	0	0	0	0	2
Cotton mouse	Peromyscus gossypinus	546	83	73	702	473	39	29	541	1243
Golden mouse	Peromyscus nuttalli	212	53	46	311	156	21	34	211	522
Rice rat	Oryzomys palustris	128	0	0	128	52	1	7	60	188
Hispid cotton rat	Sigmodon hispidus	401	213	830	1444	408	189	911	1508	2952
Eastern woodrat	Neotoma floridana	214	129	314	657	129	220	24	598	1255
Pine vole	Pitymys pinetorum	0	0	3	3	0	2	0	2	5
House mouse	Mus musculus	1	0	0	1	0	0	0	0	1
Virginia opossum	Didelphis virginiana	0	0	0	0	0	7	6	13	13
Eastern cottontail	Sylvilagus floridanus	0	0	0	0	10	1	0	11	11
S. flying squirrel	Glaucomys volans	0	2	10	12	1	0	0	1	13
Number species		9	7	8	11	9	10	8	11	13
Number individuals		1759	578	1382	3719	1370	492	1270	3132	6851

phenomenon. Also, it is possible that the marking procedure, i.e. toe clipping, was more traumatic for smaller rodents. Finally, the fact that cotton rats and woodrats ranked 1st and 3rd in numbers of individuals captured contributed to their relatively high numbers of recaptures.

Table 6. Total numbers of small mammals captured by species and tree size class, and numbers recaptured 1, 2, 3, and 4 seasons after the original capture.

Species	Total no. capt.	Number recaptured after 1	2	3	4 seasons
	---------Seedling-------				
F. harvest mouse	351	29	2	0	0
Cotton mouse	103	6	1	0	1
Golden mouse	67	4	1	0	0
Rice rat	35	0	0	0	0
H. cotton rat	804	108	4	4	4
E. woodrat	163	8	7	5	3
	---------Sapling--------				
F. harvest mouse	47	3	1	0	0
Cotton mouse	73	3	0	0	0
Golden mouse	156	4	2	1	0
Rice rat	23	5	0	0	0
H. cotton rat	130	10	1	0	0
E. woodrat	230	18	4	3	2
	----------Pole----------				
F. harvest mouse	24	0	0	0	0
Cotton mouse	218	19	3	0	0
Golden mouse	91	6	0	0	0
Rice rat	7	0	0	0	0
H. cotton rat	4	0	0	0	0
E. woodrat	56	3	1	0	0
	--------Sawtimber-------				
F. harvest mouse	11	1	0	0	0
Cotton mouse	157	15	2	0	0
Golden mouse	58	3	1	0	0
Rice rat	1	0	0	0	0
H. cotton rat	4	0	0	0	0
E. woodrat	73	5	1	2	1

Differences Between Seasons

With the exception of cotton rats, we had more total captures of each small mammal species during winter than spring (Table 4). Higher spring cotton rat captures may have been associated with the drought induced population decline in 1981 followed by the population boom in 1982. All of the opossums and cottontails were captured in the spring and were immature animals. In winter, these species were too large to enter the traps.

The most notable spring to winter decrease was in numbers of fulvous harvest mice, which declined 62% between seasons. Rice rats, golden mice, cotton mice and woodrats showed 53, 32, 23 and 9% declines, respectively. Cotton rats increased 4%. Other studies in Texas and Louisiana have shown similar results (Kroll et al. 1980, Smith 1983).

These data indicate that there is commonl major decline in the numbers of small mammals trapped from winter to spring. However, wheth this decline is a result of reduced trap susceptibility during spring or a real reducti in numbers of animals present is unknown.

Differences Between Years

As a result of the drought during the sum of 1980, there were major differences in captu numbers among each species between years. Dur the 1st trapping period after the drought (wint 1981), numbers trapped declined for each specie Except woodrats, all declined during the 2nd trapping period (spring 1981) also. In Louisiana, similar results were found (Constant 1983).

Among mouse species, the greatest decline occurred in numbers of cotton mice (Fig. 3). Declines in numbers of fulvous harvest mice and golden mice were similar. Numbers of shorttail shrews captured were low throughout the study. However, numbers captured declined during both trapping periods in 1981, and then increased during both trapping periods in 1982 (Table 4, Fig. 4).

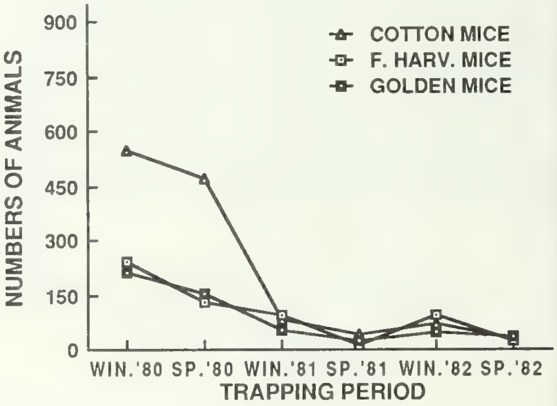
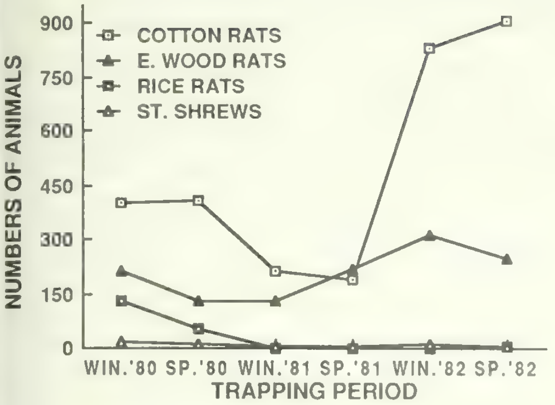


Figure 3. Total numbers of fulvous harvest, cotton and golden mice captured (including recaptures) during each 1 day trapping period.

Hispid cotton rats demonstrated the most drastic responses to the drought (Fig. 4). In t year following the drought (1981), capture numbe captured declined approximately 50%, then increased approximately fourfold from 1981 to 1982. Eastern woodrat captures demonstrated a similar pattern, although not as pronounced (Fig. 4). Rice rats were virtually eliminated with on 8 being captured during the 4 trapping periods following the drought (Table 4). This species feeds and nests in marshy areas (Burt and Grossenheider 1976) and there were no such areas



igure 4. Total numbers of rice rats, hispid cotton rats and eastern woodrats and shorttail shrews captured (including recaptures) during each 14 day trapping period.

n or adjacent to any of the study areas during ummer 1980.

The rapid recovery of the hispid cotton rats rom the adverse impacts of the drought could be ttributed to a number of factors. The species is xtremely prolific (Burt and Grossenheider 1976) nd is capable of rapidly colonizing favorable abitat. Almost 90% of the cotton rats captured were in seedling study areas. Most of the remainder were sapling study area captures (Table 4).

Fulvous harvest mice and eastern woodrats were also commonly captured on the seedling study areas. Captures of both species increased in winter 1982, although not in the magnitude of cotton rats (Figs. 3 & 4). Neither species has the biotic potential of cotton rats (Burt and Grossenheider 1976).

Neither cotton mouse or golden mouse captures increased in 1982. Both species are seed-eaters (Burt and Grossenheider 1976). This suggests that the vegetation did not recover sufficiently in the spring and summer of 1981 to allow these 2 species to increase in numbers. It is also possible that competition from the 2 rat species adversely impacted the mice during 1982.

Differences Between Tree Size Class Study Areas

Total numbers of small mammal species captured did differ among study years and between tree size class study areas during both seasons (Tables 4 and 7). During both trapping periods, total numbers of species and individuals captured were highest in seedling study areas and declined as stand age increased.

Of the 13 species captured, all except flying squirrels were recorded at least once in seedling stands. The cotton mouse was the only species captured on all 16 study areas. Fulvous harvest mice, rice rats and cotton rats were all captured in greater numbers in seedling stands than in the remaining stands (Figs. 5 & 6). Numbers of woodrats, shorttail shrews and golden mice captured peaked in the sapling stands. Numbers of cotton mice were highest in the pole study areas; that is the only target species for which number of captures peaked in either the pole or sawtimber stands. Numbers captured for all other species declined from the sapling to the pole study areas. As compared to the pole stands, numbers of woodrats and shrews increased slightly in the sawtimber stands; all other species declined and fulvous harvest mice, rice rats and cotton rats were almost excluded (Figs. 5 & 6). As would be expected, the numbers of flying squirrels captured were highest in the sawtimber study areas (Table 7). Generally, our data are similar to that of other researchers working in the South (Atkeson and Johnson 1979, Kroll et al. 1980, Kitchings and Levy 1981, Smith 1983, Fleet and Dickson 1984). Whiting and Fleet (1985) discuss similarities and differences in the small mammal communities in detail.

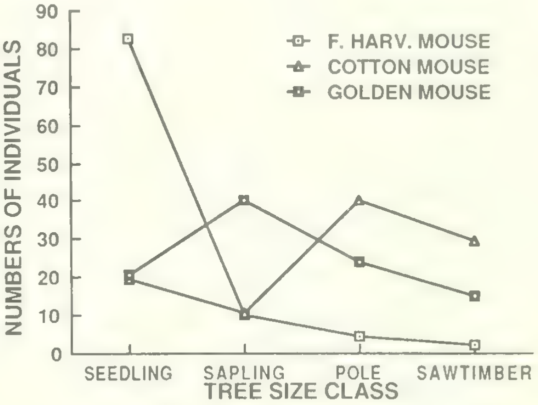


Figure 5. Total numbers (winter and spring combined) of fulvous harvest, cotton and golden mice captured in the study areas of each tree size class.

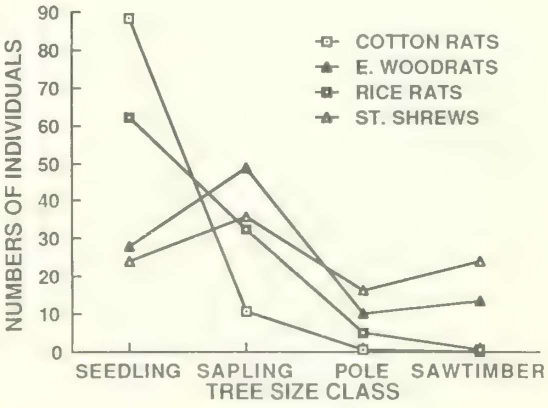


Figure 6. Total numbers (winter and spring combined) of rice rats, cotton rats, eastern woodrats and shorttail shrews captured in the study areas of each tree size class.

Table 7. Total numbers of individual mammals by species as recorded (captures and recaptures) in study areas of each tree size class during winters and springs of 1980, 1981 and 1982.

	Seedling				Sapling				Pole				Sawtimber			
Species	1980	1981	1982	Totl	1980	1981	1982	Totl	1980	1981	1982	Totl	1980	1981	1982	Totl
Winter																
Shorttail shrew	5	1	1	7	6	3	3	12	1	0	1	2	3	0	4	7
F. harvest mouse	196	83	90	369	19	9	5	33	15	2	1	18	10	0	1	11
E. harvest mouse	1	0	0	1	1	0	0	1	0	0	0	0	0	0	0	0
Cotton mouse	127	37	19	183	66	1	8	75	210	33	18	261	143	12	28	183
Golden mouse	25	13	10	48	81	25	18	124	60	10	11	81	46	5	7	58
Rice rat	110	0	0	110	12	0	0	12	6	0	0	6	0	0	0	0
H. cotton rat	377	199	793	1369	21	14	33	68	3	0	3	6	0	0	1	1
E. woodrat	37	54	91	182	124	64	147	335	20	11	32	63	33	0	44	77
Pine vole	0	0	3	3	0	0	0	0	0	0	0	0	0	0	0	0
House mouse	1	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0
S. flying squirrel	0	0	0	0	0	1	0	1	0	0	3	3	0	1	7	8
Total Species	9	6	7	10	8	7	6	9	7	4	7	8	5	3	7	7
Total Individ.	879	387	1007	2273	330	117	214	661	315	56	69	440	235	18	92	345
Spring																
Shorttail shrew	3	1	1	5	2	1	3	6	4	0	2	6	2	1	2	5
F. harvest mouse	95	7	22	124	25	0	2	27	6	2	2	10	4	0	0	4
E. harvest mouse	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Cotton mouse	48	10	2	60	53	1	1	55	209	19	12	240	163	9	14	186
Golden mouse	42	7	10	59	60	11	15	86	36	2	7	45	18	1	2	21
Rice rat	2	1	4	7	47	0	2	49	2	0	1	3	1	0	0	1
H. cotton rat	314	126	805	1245	87	63	100	250	7	0	0	7	0	0	6	6
E. woodrat	7	70	91	168	65	102	109	276	25	18	22	65	32	30	31	93
Pine Vole	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0
Virginia opposum	0	1	1	2	0	0	1	1	0	6	1	7	0	0	3	3
E. cottontail	7	1	0	8	3	0	0	3	0	0	0	0	0	0	0	0
S. flying squirrel	0	0	0	0	0	0	0	0	0	0	0	0	1	0	0	1
Total Species	8	10	8	10	8	5	8	9	7	5	7	8	7	4	6	9
Total Individ.	518	226	936	1680	342	178	233	753	289	47	47	383	221	41	58	320

Differences Among Tree Size Class Study Areas

There were significant differences in numbers of individuals and species diversity and equitability values among all tree size class study areas. Cottontails, opossums and flying squirrels were not used in calculating species diversity and equitability values. Also, in some study areas we captured as many as 11 individuals of 3 species during a trapping period, yet average species diversity and equitability values were zero (Whiting and Fleet 1985). This is a result of the fact that we captured members of only 1 species on any given census-day.

Seedling study areas.--With the exception of winter 1982, there were significant differences between the seedling study areas in numbers of small mammals captured during each study season (Table 8). Generally, numbers of captures were lowest on the site prepared, planted seedling study area, i.e. 9. This was a result of intensive site preparation which took place prior to and during the 3 year sampling period. These activities eliminated the debris and small woody plants that were common on the other seedling study areas. However, as a result of the relatively moist summer of 1981, numbers of cotton rats captured in that study area in 1982 increased to the extent that the differences among study areas were not significant during winter. In the spring, significantly more were captured there than on study areas 5 and 13 (Table 8). As cotton rats are herbaceous feeder and the vegetation was dominated by grasses and herbaceous plants, this was not unexpected.

During several seasons, numbers of species and individuals captured were highest in study area 1 (Table 8). The stand was probably the most diverse; it had the most residual trees and tree species. Residual trees were larger than i other seedling stands (Table 1). Also, more of the study area was occupied by a stream, which had water in it more regularly than other seedling stands. Finally, a young planted pine plantation was within 240 ft of the study area. Mature mixed pine-hardwood stands also juxaposed the study area. Probably some of the animals captured were dispersing from adjacent habitats.

When data were combined by season and teste between study areas, there were significant differences in numbers of captures (Table 8); generally the same was true when data was combine by year and compared. During 1982, cotton rats comprised 76, 74, 97 and 81% of captures in stud areas 1, 5, 9 and 13 respectively. This emphasizes the biotic potential of the species 'able 8. Total numbers of species and individuals and average species diversity (H') and equitability (J) values for small mammals recorded in each study area by year and season. Combined seasonal values are also shown.

		Winter				Spring			
		Total		Average		Total		Average	
'ear	Stand no.	Spec.	Indiv.	H'	J	Spec.	Indiv.	H'	J
				Seedling					
1980	1	8	327	1.3010	0.8255	6	165	0.9412	0.8346
	5	7	216	1.3610	0.8450	6	94	0.8622	0.7913
	9	3	72	0.4878	0.6636	4	38	0.2112	0.3105
	13	6	264[a]	0.8032[a]	0.6507[a]	6	221[a,c]	0.6170[a,c]	0.6066[a,c]
1981	1	5	81	0.7805	0.7469	6	48	0.6128	0.6821
	5	5	66	0.7774	0.7166	5	68	0.6742	0.8268
	9	2	28	0.0455	0.0656	5	16	0.0743	0.0676
	13	6	212[a]	1.0126[a]	0.7673[a]	6	94[a,c]	0.6957[a,c]	0.8633[a,c]
1982	1	7	265	0.8489	0.6637	4	253	0.5518	0.5337
	5	4	242	0.8279	0.8026	6	198	0.4080	0.4278
	9	2	244	0.1476	0.2129	3	284	0.0719	0.0816
	13	5	256	0.4314[a]	0.4797[a]	5	201[a]	0.5498[a,b]	0.7148[a,c]
Comb.	1	9	673	0.9768	0.7454	8	466	0.7019	0.6835
	5	7	524	0.9888	0.7881	8	360	0.6481	0.6820
	9	3	344	0.2270	0.3140	6	388	0.1191	0.1532
	13	8	732[b]	0.7490[b]	0.6326	8	516[b]	0.6208[b]	0.7282[b]
				Sapling					
1980	2	8	122	1.1212	0.8487	7	150	0.8287	0.7151
	6	5	45	0.4794	0.5431	6	75	0.9150	0.8648
	10	4	26	0.2640	0.2667	4	43	0.6515	0.7448
	14	7	137[a]	0.7899[a]	0.7742[a]	6	74[a,c]	0.8518	0.9255[a]
1981	2	5	39	0.4372	0.5510	3	106	0.6449	0.7228
	6	2	24	0.0874	0.1261	2	23	0.0455	0.0656
	10	4	17	0.1064	0.1252	3	11	0.0000	0.0000
	14	3	37[a]	0.3609[a]	0.5207[a]	3	38[a,c]	0.1149[a,c]	0.1658[a,c]
1982	2	5	96	0.7901	0.6964	7	89	0.6883	0.7290
	6	2	32	0.0455	0.0656	3	38	0.0495	0.0714
	10	2	11	0.0495	0.0714	2	35	0.4054	0.5849
	14	6	75[a]	0.3738[a]	0.3681[a]	4	71[a,c]	0.5160[a,c]	0.6349[a,c]
Comb.	2	8	257	0.7828	0.6987	9	345	0.7206	0.7223
	6	6	101	0.2041	0.2449	6	136	0.3367	0.3339
	10	6	54	0.1320	0.1544	5	89	0.3523	0.4432
	14	7	249[b]	0.5082[b]	0.5543[b]	6	183[b]	0.4942[b]	0.5744
				Pole					
1980	3	5	101	0.3744	0.4114	5	96	0.5768	0.5652
	7	6	88	0.9460	0.8576	6	69	0.9119	0.8865
	11	3	46	0.1931	0.2786	2	59	0.1527	0.2203
	15	4	80	0.2037[a]	0.2152[a]	3	65[a,c]	0.1743[a,c]	0.2212[a,c]
1981	3	2	14	0.0402	0.0580	3	17	0.0000	0.0000
	7	4	23	0.2847	0.3482	3	17	0.1819	0.2740
	11	2	7	0.0000	0.0000	2	9	0.0495	0.0714
	15	2	12	0.0495[a]	0.0714[a]	3	4[a,c]	0.0785[c]	0.0714[c]
1982	3	2	6	0.0000	0.0000	2	3	0.0000	0.0000
	7	5	41	0.4236	0.5748	5	23	0.1959	0.2046
	11	3	20	0.1445	0.2085	3	11	0.0000	0.0000
	15	2	2	0.0000	0.0000	4	10[a,c]	0.0950[c]	0.1370[c]
Comb.	3	5	121	0.1392	0.1565	6	116	0.1923	0.1884
	7	6	152	0.5514	0.5935	7	109	0.4299	0.4550
	11	5	73	0.1125	0.1624	3	79	0.0674	0.0972
	15	5	94	0.0844	0.0955	5	79	0.1159[b]	0.1432[b]

Continued on next page.

Table 8. Continued.

Year	Stand no.	Winter				Spring			
		Total		Average		Total		Average	
		Spec.	Indiv.	H'	J	Spec.	Indiv.	H'	J
		Sawtimber							
1980	4	4	69	0.3646	0.3828	3	25	0.0803	0.1159
	8	3	58	0.7726	0.8037	5	95	0.7359	0.8333
	12	3	40	0.3781	0.4352	4	45	0.3364	0.3687
	16	4	68	0.3869[a]	0.4628[a]	3	56[a,c]	0.2712[a,c]	0.3582[a,c]
1981	4	0	0	0.0000	0.0000	2	2	0.0000	0.0000
	8	2	5	0.0000	0.0000	4	18	0.1692	0.2046
	12	3	11	0.0000	0.0000	2	8	0.0000	0.0000
	16	2	2[a]	0.0495	0.0714	2	13[a,c]	0.1859[a,c]	0.2682[a,c]
1982	4	3	6	0.0455	0.0656	4	17	0.1957	0.3437
	8	4	39	0.1749	0.2524	3	23	0.0455	0.0656
	12	2	19	0.0976	0.1408	3	11	0.1280	0.1429
	16	7	28[a]	0.2591	0.2696	4	7[c]	0.0990	0.1429
Comb.	4	5	75	0.1367	0.1495	4	44	0.0920	0.1532
	8	4	102	0.3158	0.3520	6	136	0.3169	0.3678
	12	4	70	0.1586	0.1920	5	64	0.1548	0.1705
	16	7	98[b]	0.2318	0.2679	6	76[b]	0.1854[b]	0.2564

[a] Indicates a significant difference, at the 0.05 level, between values for study areas of the same tree size class within a season. Differences in numbers of species were not tested.

[b] Indicates a significant difference, at the 0.05 level, when data for the same 3 seasons were combined ar tested between study areas of the same tree size class.

[c] Indicates a significant difference, at the 0.05 level, when data were combined by year (i.e. winter and spring) and tested between study areas of the same tree size class.

and suggests that the 3 seedling areas which were naturally regenerated met cotton rat habitat requirements almost equally.

Sapling study areas.--During all 6 sampling periods, there were significant differences in numbers of captures among the sapling study areas (Table 8). Relatively high numbers in study areas 2 and 14 were due to the presence of windrows. Study area 14 was mechanically thinned in early spring 1980 and numbers of captures declined from winter to spring 1980 (Table 8). That numbers captured did not increase from winter to spring 1981 as did numbers in study area 2 was also related to the thinning. Low numbers in study areas 6 and 10 were because both had been clearcut, prescribed burned, then broadcast seeded to shortleaf pine, thus there were no windrows and very little debris present.

Pole study areas.--During 1980 only, study area 3 ranked highest in numbers of animals captured (Table 8). During spring, the differences were significant. High 1980 capture numbers were due to the abundance of cotton and golden mice (Whiting and Fleet 1985). Both study area 3 and study area 15, which was directly across state highway 47 from study area 3, showed severe post-drought declines in numbers of animals captured. Rakowitz (1983) characterized the understory of study area 3 as atypical, containing large numbers of open patches dominated by volunteer loblolly pine seedlings. From summer 1980 to winter 1981, declines in the proportions of woody plants in the understory (Whiting and Fleet 1985), demonstrated that many of the pine seedlings present in 1980 died as a result of the drought. Before the drought, it i likely that these seedlings provided cover for the cotton and golden mouse communities. After the drought, suitable cover was no longer present.

Sawtimber study areas.--Significantly greater numbers of small mammals were captured o study area 8 than on other sawtimber study areas during spring 1980 (Table 8). High numbers of cotton mice and woodrats captured were a result of differing vegetational characteristics. Small vegetation on this stand was significantly different from that of the remaining sawtimber study areas in several ways (Whiting and Fleet 1985). There were more plant species and individuals and thus higher plant species diversity values were recorded there. Also, small vegetation was somewhat taller and dominated by poison ivy, (Toxicodendron radicans) and more grass occurred in the understory and ground cover (Rakowitz 1983).

During winter 1981, only 12 individuals were captured in the sawtimber stands; the remaining 6 were recaptures. During spring of that year, only 20 different individuals were captured. Numbers of individuals captured did not increase greatly in 1982, with 33 during winter and 28 during spring. These data support Dueser and Shugart's (1978) suggestion that older pine communities may be ecologically saturated, even at low rodent densities.

Summary.--There were differences in the small mammal communities between the various tree size class stands. The seedling study areas were utilized by a wider variety of species and more individuals than were the remaining study areas. Numbers of species and individuals generally decreased as size of the trees on the study area increased. There were also differences between study areas of the same tree sizes. These differences were no doubt a result of variations in previous forest management practices and soil/site factors.

Perhaps most notable were the drought effects on small mammal communities. Captures of 5 of the 6 common species declined drastically after the drought. Only cotton rats recovered to or above predrought numbers during the remainder of the study period.

OTHER MAMMALS

We made 4 squirrel censuses and 2 squirrel nest counts on the pole and sawtimber study areas. Generally we recorded more squirrels in the sawtimber than the pole study areas. More squirrels and a higher density were recorded on study area 4 than on the other study areas. This is no doubt a result of the fact that pines comprised a lower proportion of the overstory there (Whiting and Fleet 1985).

Numbers of squirrel nests varied widely among the pole and sawtimber study areas and we were unable to relate numbers of squirrel nests to numbers of squirrels. It is likely that the numbers of nests were inversely related to the numbers of den trees present, perhaps more strongly than to the numbers of squirrels present. Of possible interest was a fox squirrel seen after dark on the ground in a sawtimber stand during a spring night spotlight census.

We recorded large and mid-sized mammals seen or heard incidental to bird and small mammal censuses during 1980 and 1981. There were no obvious trends in numbers recorded among study areas. However, during both seasons, more white-tailed deer and cottontails were tallied than any other species. Fewer total animals were recorded during winter than during spring.

During fall night spotlight censuses, we recorded 68 individuals of 9 large and mid-sized mammal species; during spring, we tallied 77 individuals of 8 species (Whiting and Fleet 1985). Less than 2 animals per census-hour were recorded, thus these censuses were discontinued after spring 1981. There were no trends in numbers of animals recorded among the various study areas. During both seasons, we tallied more armadillos than any other species. Cottontails ranked 2nd.

In summary, neither the squirrel nor the large to mid-sized mammal census technique proved to be satisfactory. All were too labor intensive and costly for reliable data collection.

CONCLUSIONS

Due to the unavailability of ideal stands for each tree size class, there were differences in flora and fauna among stands of the same tree size classes. As a result, differences between tree size class study areas were not tested. Generally, differences among tree size class study areas were greatest for the seedling study areas. The differences were due largely to the past forest management practices. Variations in soil/site factors were probably of secondary importance on the seedling study areas. As stand age increased, the effects of past forest management practices decreased and the influence of soil/site factors increased.

Examination of the vegetational data did indicate that differences among study areas of the same tree size class were much less than were differences between study areas of the different tree sizes. As a result, both the bird and small mammal community structures varied greatly between the seedling, sapling, pole and sawtimber study areas. Generally, the highest numbers of species and individuals of both birds and small mammals were recorded on the seedling study areas. Numbers of both birds and mammals generally decreased as stand age increased.

An extreme drought after the 1st sample year adversely impacted both birds and small mammals. Most noteworthy was the trend in cotton rat numbers which crashed following the drought and rebounded strongly the following year. Excluding eastern woodrats, populations of the remaining small rodents also crashed after the drought, and had not recovered 2 years thereafter. Numbers of woodrats captured declined in the trapping period immediately following the drought, but recovered by the next period. These data suggest that the high numbers of cotton rats during the 2nd year after the drought prevented the remaining small rodent species from recovering as rapidly as did the cotton rats.

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Soils of the Loblolly/Shortleaf and Longleaf/Slash Pine Project:

Grant and Vernon Parishes, Louisiana

W. Wayne Kilpatrick

The purpose of the soil survey conducted on United States Forest Service land was to use soil types as a baseline environmental setting upon which the vegetation could be superimposed. It is assumed that a correlation exists between vegetation and soil types. This documented correlation could be of benefit to future and present studies.

The soil survey for the Forest Range Project Grant Parish was completed in July 1979. It onsists of approximately 8,000 acres of loblolly-ortleaf forest types. The Vernon Parish soil rvey Range Project was completed in August 1979, d consists of approximately 6,785 acres of long-eaf-slash forest types.

Soil delineations were based on soil series, rface texture, slope percent and other factors, ch as flooding. Procedures and standards were llowed according to the National Soils Handbook.

The soils of the project area contain a full rray of textures. These range from loose coarse oamy soils to dense sticky clayey soils, and from e well drained soils on the uplands to the poorly rained soils of the floodplains in the upland rainageways.

The Grant Parish study area is located pproximately 15-20 miles north of Alexandria in entral Louisiana. Soils in the project area of rant Parish formed in parent material of Pleistocene Age. The study area consists of Prairie, ontgomery, and Bentley terraces. The Bentley erraces are the oldest and were formed as deltaic lains of the Mississippi River. They have been ontinuously exposed to weathering and soil ormation since their deposition more than 300,000 ears ago. The Bentley terrace is best developed n central Grant Parish where it is preserved as narrow area at the foot of a fairly well defined scarpment one mile north of Bentley.1/ The oils developed in these deposits are mainly eauregard, Malbis, Ruston, and Smithdale soils. hey are highly weathered and leached and are haracterized by a distinct B horizon of secondary ccumulations of clay. These soils are classified s Ultisols and, consequently, have low base tatus and acid soil reactions throughout. ypically, the base status and soil reaction are highest in the surface horizon and decrease with depth into the B horizon. In most areas, the reaction and base status do not increase at greater depths within the soil because of the highly weathered and leached conditions.

Sediments of the Montgomery Terrace Formation are intermediate in age between Bentley and Prairie terraces. The principal occurrence of the Montgomery terrace is in the form of a coastwise terrace of fluvial and possibly deltaic origin located in southeastern Louisiana.2/ The parent material of these soils has been continuously exposed to weathering and soil formation since their deposition more than 100,000 years ago. Although highly weathered and leached, soils developed on the Montgomery Terrace, such as Guyton, are higher in bases and generally have higher reaction in the lower horizons than soils formed on the Bentley terraces. Typically, their base saturation and soil reaction increase with depth in the lower solum. These soils have a distinct B horizon of secondary accumulations of clay and are classified as Alfisols.

The youngest of the four major Pleistocene Terrace formations, the Prairie, was deposited as upper deltaic or lower alluvial plains of the Mississippi and Red Rivers. It has been continuously exposed to weathering and soil forming processes since its deposition perhaps 30,000 or more years ago.

The terrace deposits of the Prairie Formation are the parent material of the Gore soils. These soils are in areas that flank the escarpments of some drainageways in the uplands. Gore soils formed in reddish calcareous clays. They are classified as Alfisols and, as such, have a B horizon characterized by secondary accumulations of clay. Typically, soil reaction and base saturation decrease with depth from the surface horizon

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. Wayne Kilpatrick, Soil Scientist, USDA Soil Conservation Service, Minden, Louisiana.

to minimum values in the upper part of the B horizon. Below these minimum levels, reaction and base status typically increase with depth.

The Vernon Parish project area is located in western Louisiana approximately 35-40 miles northwest of Alexandria. Soils in this project area are of parent material similar to the Grant Parish project. Landscape consists of nearly level to gently sloping soils. The more sloping soils are adjacent to drainageways which dissect the area. Loamy Cahaba soils are delineated along low-lying terraces in the Vernon Parish project area. Figure 1 shows the proximity of the project areas.

A comparison of temperature and precipitation for the Grant and Vernon Parish project areas is depicted in Figure 2. The top figure is data collected at Esler Field which is very near the Grant project area. The bottom portion of the table is data from Elizabeth, Louisiana near the Vernon project area. The main difference depicte is the average daily maximum and average total precipitation. The average daily maximum differs by 2 degrees, and the average precipitation diffe by 2.1 inches.

Approximately 50 percent of the precipitatio usually falls in April through September. The growing season for most plants falls within this time period. The heaviest one-day rainfall durin the period of record was nine and one-half inches at Belah on April 29, 1953. Thunderstorms occur about 70 days each year, and most occur in summer

The average relative humidity in mid-afterno in these areas is about 60 percent. Humidity is higher at night, and the average at dawn is about 90 percent. The sun shines 60 percent of the tim possible in summer, and 50 percent in winter. Th prevailing wind is from the south. Average windspeed is highest, 6 miles per hour, in spring.

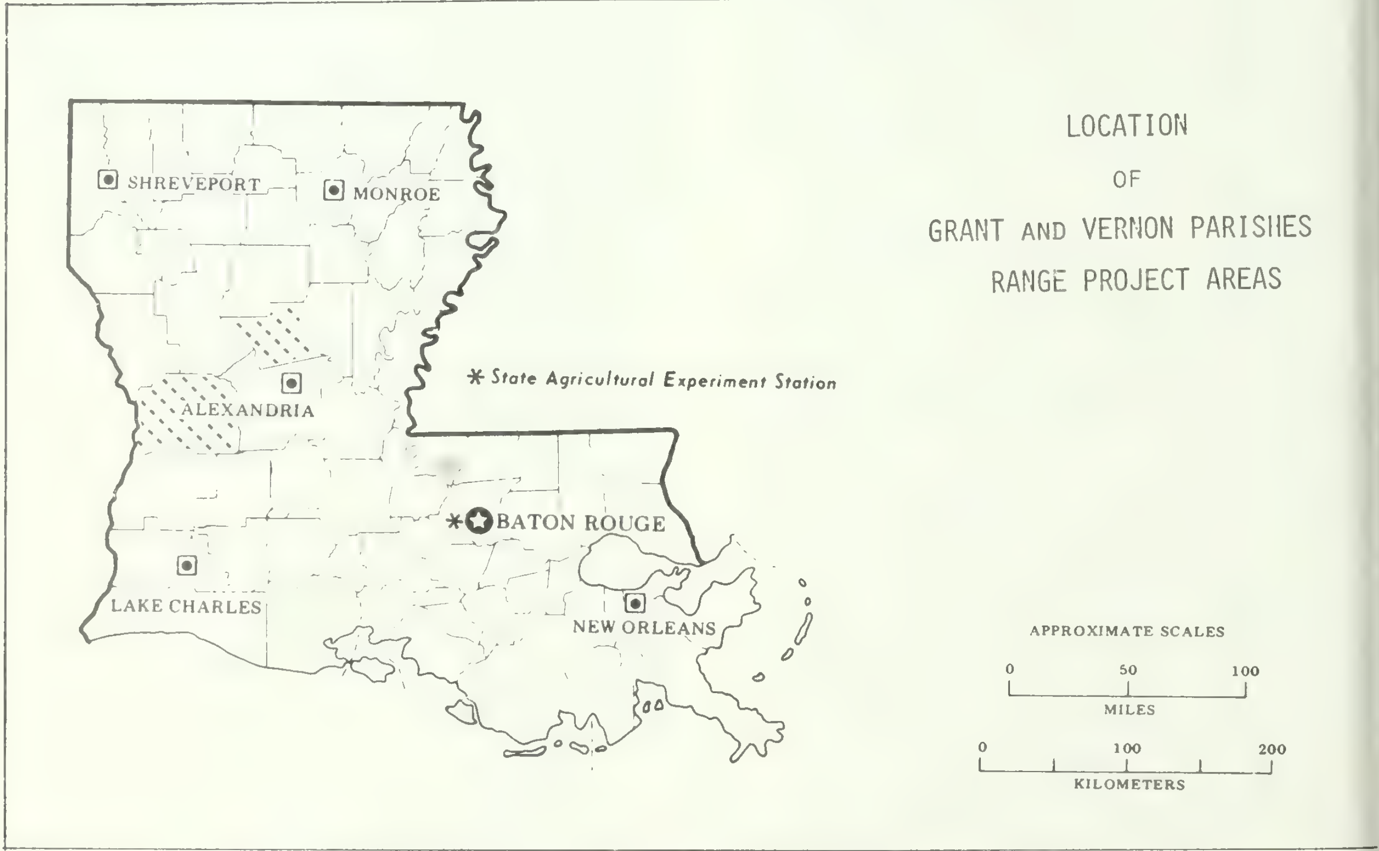

Figure 1.--Location of Grant and Vernon Parishes Range Project Areas

TEMPERATURE and PRECIPITATION DATA
(Recorded in the period 1941-70 at Elizabeth, Louisiana)

Month	Temperature					Precipitation		
	Average Daily Maximum	Average Daily Minimum	Extreme Maximum and Minimum	2 years in 10 will have-- Maximum Temperature Higher Than--	2 years in 10 will have-- Minimum Temperature Lower Than--	Average	2 years in 10 will have-- Lower Than--	2 years in 10 will have-- Higher Than-
	°F	°F	°F	°F	°F	In.	In.	In.
January. . . .	61	38	82/6	80	17	4.9	2.9	7.1
February . . .	64	40	85/6	80	21	4.9	2.8	6.8
March.	71	46	90/20	86	28	5.1	3.2	7.7
April.	79	56	93/33	89	35	5.6	2.3	8.0
May.	85	62	100/42	94	46	5.0	2.9	8.4
June	91	68	106/51	98	55	5.0	2.2	7.9
July	93	70	103/54	100	64	5.1	2.8	7.9
August	93	70	107/58	103	60	4.1	2.7	5.3
September. . .	89	65	103/36	98	49	4.2	2.4	6.8
October. . . .	82	54	98/31	94	34	3.5	0.6	5.6
November . . .	71	45	88/24	87	26	4.6	2.2	6.7
December . . .	64	40	83/16	80	20	6.3	3.6	8.6
YEAR. . . .	79	55	107/6	102	16	59.1	50.8	68.0

Figures 2 & 2A.--Temperature and Precipitation Comparison Data

TEMPERATURE and PRECIPITATION DATA
(Alexandria, Louisiana - Esler Field)

Month	Temperature				Precipitation		
	Average Daily Maximum	Average Daily Minimum	Average Highest	Average Lowest	Average total	One year in 10 will have-- Less than-	One year in 10 will have-- More than-
	°F	°F	°F	°F	In.	In.	In.
January	59	38	76	18	5.0	1.9	8.4
February.	63	40	78	23	4.9	2.0	8.3
March	70	46	82	29	5.1	1.8	9.4
April	78	56	87	39	5.4	1.8	9.5
May	85	62	92	48	5.7	1.8	10.8
June.	90	69	96	58	4.4	1.4	8.2
July.	93	72	98	65	5.1	1.8	8.9
August.	92	71	98	63	3.6	.9	7.2
September	88	66	94	52	3.4	.9	7.0
October	80	54	90	37	3.6	.7	8.0
November.	69	45	83	27	5.0	.9	10.6
December.	61	39	77	23	6.0	3.4	11.9
Year	77	55	99	17	57.2	43.2	72.7

The following graph (fig. 3), shows surpluses and deficits of water in inches by seasons. The data was collected over a period of 29 years.

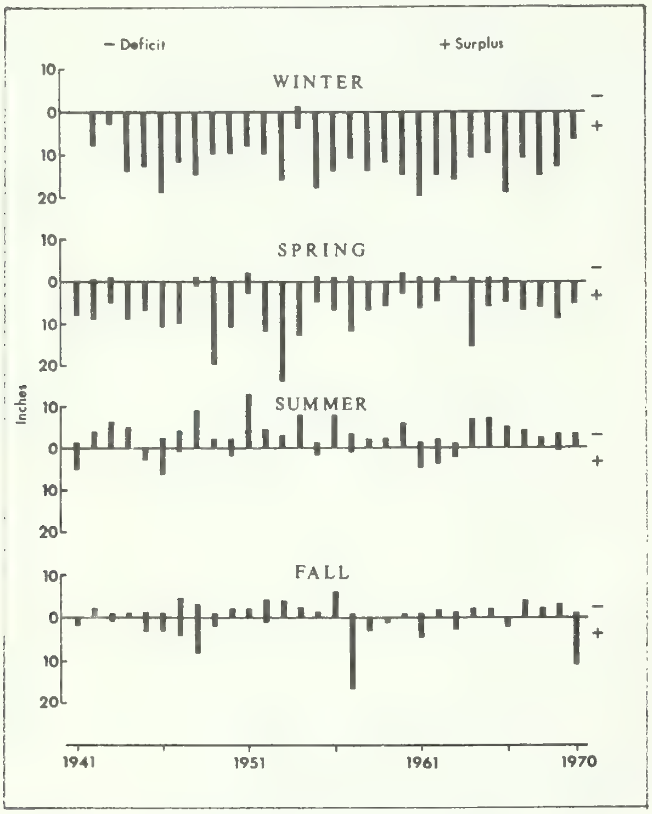

Figure 3.--Monthly water-budget surpluses and deficits in inches, by season. Recorded in the period 1941-70 at Elizabeth, La.

METHOD

Soil scientists went over the area and studied the soils to depths of 4 to 6 feet. After examining the color of the soil, the texture, structure, and the thickness of the varying layers, they classified the soil using a nationwide system of soil classification. Then they plotted the boundaries on aerial photographs and placed a symbol within each delineation. For example, the symbol 81 indicates the soil is Gore silt loam, 1 to 5 percent slope. All soils with the same symbol have the same name, and are called soil mapping units. There is no general rule for guiding the number of soil examinations required per unit area, nor for the intervals between transverses, except that these can rarely be more than one-fourth mile wide and usually need to be narrower. 3/ Every effort is made to include within any one delineation, only those conditions a are indicated by the mapping unit name. Even wi care, there are in most delineations, inclusion similar and sometimes dissimilar soils which ar not indicated on the map.

The two major reasons for mapping unit incl sions are the scale of the map and the character of the soils. Using the map scale, it is diffic to show areas smaller than 3 acres in size. Als the width of a pencil line on the map represents several feet on the ground. Soils, except in ra cases, do not have distinct boundaries, but grad ally change from one to another. This change ma take place in a few feet, or 50 to 100 feet. Th soil scientist, with a reasonable amount of investigation, must draw a line somewhere indica a change from one soil to another while keeping transitions to a minimum on either side of the line.

RESULTS

A typical landscape on the Grant Parish pro is shown in Figure 4. The dominant soils of the Grant Parish project are the Beauregard and Malb series that occur on level and nearly level ridg The Ruston soils occur on narrow convex ridgetop The Gore and Smithdale soils occur on sideslopes Another series in this area is the Guyton series that generally occurs on level floodplains along stream channels and drainageways. The Beauregar soil has a mottled brown, yellow, and red, friab sandy clay loam subsoil with weak, subangular blocky structure. Malbis soils have yellowish brown, friable sandy clay loam subsoil with a we blocky structure. Gore soils have red, firm cla subsoils with a weak, blocky structure. Ruston Smithdale soils have reddish loamy subsoils. Guyton soils have gray, brown-mottled, silty cla loam subsoils with a compound subangular blocky and prismatic structure.

Figure 5 shows that the dominant soils of th Vernon Parish project are the Beauregard and Malb series that occur on level or nearly level ridges and the Susquehanna series that occurs on sideslo Also in this area is the Guyton soil series that occurs along stream channels and drainageways. T Beauregard soil has a mottled brown, yellow, and red, friable sandy clay loam subsoil with a weak, subangular blocky structure, and lies on broad fl ridges. Malbis soils have yellowish brown subsoi layers, and are on convex ridgetops. Susquehanna soils have a mottled gray, brown, and red firm cl subsoil with a weak, blocky structure, and are on sideslopes. Cahaba soils have reddish loamy subsoils, and are on low terraces adjacent to major drainageways. Guyton soils have a gray, brown-mottled silty clay loam subsoil with a compound subangular blocky and prismatic structure.

3/ U.S. Department of Agriculture, Soil Conservation Service. Soil Survey Manual. Agric. Handb. 18. Washington, DC: U. S. Department of Agriculture, Soil Conservation Service; 1962. 16 p.

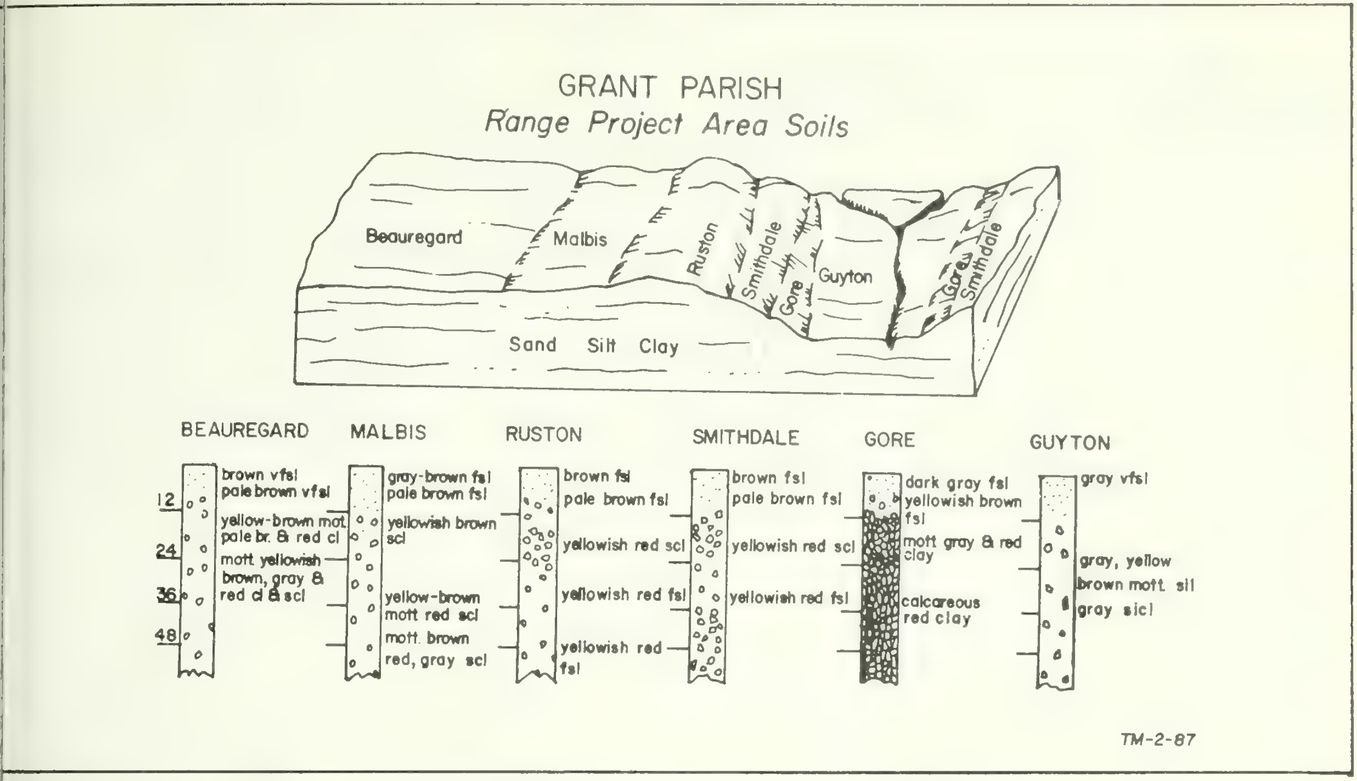

Figure 4.-Grant Parish Range Project Area Soils

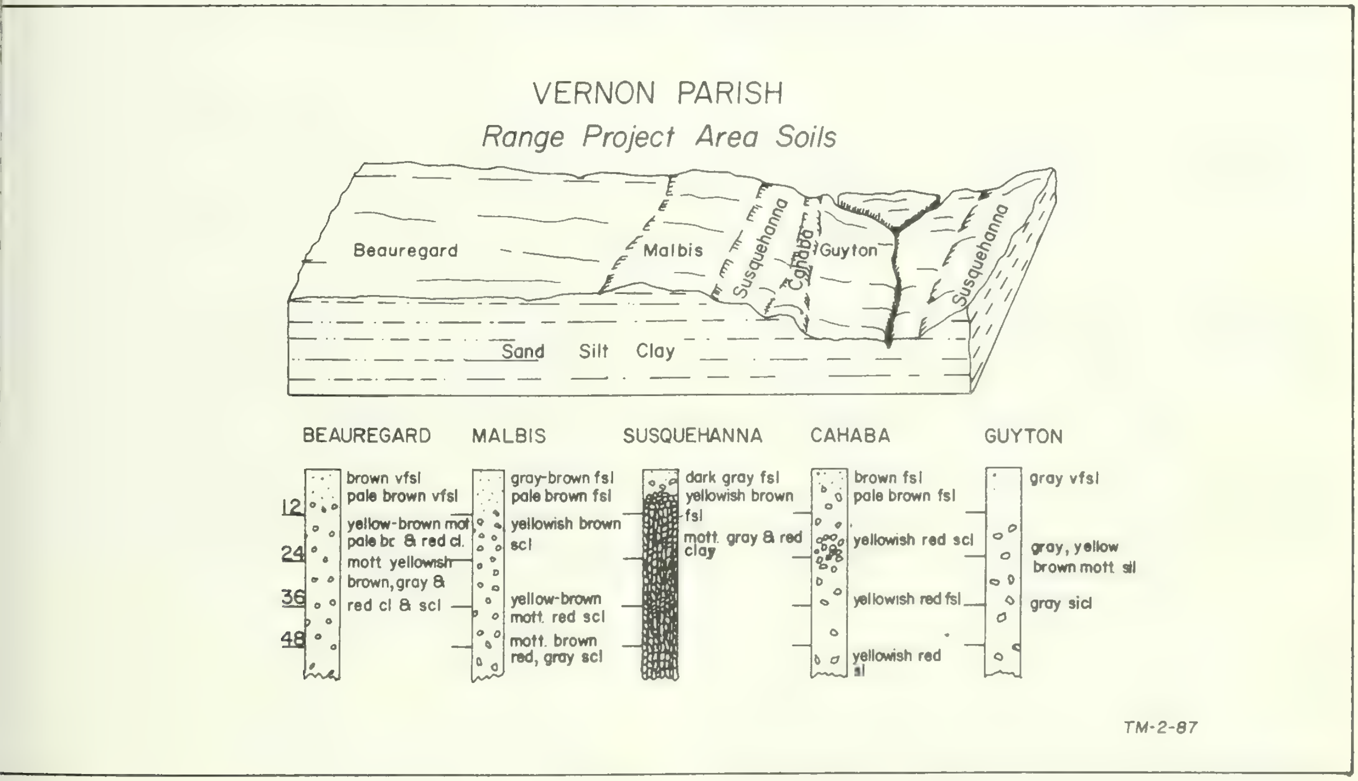

Figure 5.-Vernon Parish Range Project Area Soils

The map units on the detailed soil maps of this survey represent the soils in the survey area. The map unit descriptions, along with the soil maps, can be used to determine the suitability and potential of a soil.

Each map unit on the detailed soil maps represents an area on the landscape and consists of one or more soils for which the unit is named.

A symbol identifying the soil precedes the map unit name in the soil descriptions. Each description includes general facts about the soil, a brief description of the soil profile, and a listing of the principal hazards and limitations to be considered in planning management for woodland and range uses. The important soil properties affecting woodland and range uses are as follows:

Wetness-The upland soils are well drained or moderately well drained. Surface water runs off at a medium rate and wetness is seldom a problem. Soils in the drainageways are wet, however, and subject to flooding.

Slope-The nearly level to strongly sloping topography is no serious hazard for woodland and range uses.

Soil Erosion-The sloping upland soils in overgrazed areas and mechanically disturbed areas are subject to erosion. If uncontrolled, topsoil is lost and gullies develop. Erosion can be controlled by maintaining proper stocking rates and by using wise woodland practices during harvesting operation.

Permeability-Due to clay layers in some of the soils, downward movement of water is slow. This may create some wet conditions around supplemental feeding areas and catch-pens during the winter and early spring months. The wet conditions also may hinder woodland harvesting.

Engineering Properties-Engineering properties for pond reservoir areas and embankments for levee type ponds range from good to poor, depending on the soil. The seepage hazards and piping potentials are slight in some soils and severe in others.

Figure 6, representing some of the soils that were mapped in the project areas, show chemical data that is important in classifying soils and on effecting types of vegetation. Generally, most of the soils are acid and low in natural fertility.

The soils are placed in two orders based on the national classification system used by the Soil Conservation Service. The following soils are classified as Ultisols: Beauregard, Malbis, Ruston, Cahaba, and Smithdale. Ultisols are soils that have an argillic horizon and have a base saturation of less than 35 percent at a depth of 50 inches below the upper boundary of the argillic horizon, or at a depth of 72 inches below the surface of the soil, whichever is shallower. The remaining soils were classified as Alfisols. These soils also have a argillic horizon, but the base saturation is mor than 35 percent at the critical depths as descri above.

CHEMICAL DATA ON SELECTED SOILS

Soil Series	Depth in Inches	Horizon	USDA Texture	pH	Organic Matter	Cation Exch. Capacit	Extractable Cations					Ba Satu tio
							Ca	Mg	K	Na	H	
BEAUREGARD (Plinthaquic Paleudults)	0-3	Al	SiL	5.2	2.7	6.2	1.0	0.3	0.1	--	6.1	19
	3-8	E	SiL	5.1	.79	5.2	0.5	0.3	--	0.1	4.9	16
	8-16	BE	SiL	5.1	.34	7.3	0.2	0.4	0.1	0.1	8.1	9
	16-27	Bt1	SiL	5.2	.24	9.3	0.7	0.1	0.1	0.1	8.0	13
	27-40	Btv	SiL	5.4	.08	8.4	0.4	0.9	0.1	0.1	8.2	15
	40-60	Btvg	Sicl	5.3	.01	12.6	1.4	2.3	0.1	0.4	9.8	30
GUYTON (Typic Glossaqualfs)	0-6	A1	SiL	4.9	1.30	5.8	1.0	0.4	0.1	0.1	0.4	28
	6-13	Eg1	SiL	4.9	1.39	4.3	[illegible]	0.3	0.1	0.1	0.4	26
	13-23	Eg2	SiL	5.0	1.29	4.0	0.4	0.3	0.1	0.1	0.6	22
	23-32	E/B	SiL	5.3	0.29	7.3	0.5	0.6	0.1	0.3	1.1	20
	32-42	Btg1	Sicl	5.2	0.19	11.1	0.4	0.9	0.1	0.8	0.8	25
	42-60	Btg2	Sicl	5.1	0.15	10.6	0.7	1.1	0.1	1.4	0.9	36
CAHABA (Typic Hapludults)	0-6	A1	fsl	6.3	--	--	3.6	0.9	0.4	--	1.9	72
	6-12	E	fsl	5.4	--	--	0.7	1.2	0.4	--	2.3	51
	12-16	B/E	fsl	4.8	--	--	0.4	1.1	0.5	--	4.6	32
	16-22	Bt1	scl	4.6	--	--	0.6	1.8	0.4	--	6.6	30
	22-34	Bt2	scl	4.6	--	--	0.9	2.0	0.4	--	8.9	27
	34-46	Bt3	scl	4.6	--	--	1.4	2.2	0.4	--	10.	28
	46-65	BC	sl	4.6	--	--	0.6	1.2	0.2	--	6.5	24
MALBIS (Plinthic Paleudults)	0-4	A1	fsl	5.0	2.40	5.7	0.6	--	0.1	--	5.7	11
	4-11	E	fsl	5.4	.67	2.6	0.4	0.2	--	--	2.0	23
	11-21	Bt1	scl	5.0	.27	10.0	1.0	1.4	0.1	--	8.0	22
	21-31	Bt2	scl	5.1	.13	8.8	--	1.1	0.1	--	8.1	13
	31-43	Btv	scl	5.1	.01	8.4	--	1.1	0.1	--	6.9	15
	43-65	Btv2	scl	5.0	.01	9.2	--	1.5	0.1	--	8.1	16
RUSTON (Typic Paleudults)	0-5	A1	fsl	5.9	.98	2.9	0.8	0.4	0.1	--	2.8	32
	5-10	E2	fsl	5.5	.43	2.9	0.6	0.4	0.2	--	1.6	43
	10-17	Bt1	scl	5.3	.22	3.5	0.4	0.5	0.1	--	2.8	26
	17-27	Bt2	scl	5.2	.18	8.7	--	2.0	0.2	--	7.0	24
	27-33	B/E	fsl	5.1	.13	10.3	--	2.0	0.2	--	2.8	22
	33-45	Bt'	fsl	4.9	.10	11.5	0.6	2.9	0.2	--	8.7	30
	45-65	Bt'2	scl	4.9	.10	12.1	--	2.4	0.1	--	7.8	24

Figure 6.--Chemical Data on Selected Soils

Much valuable information about soils can b obtained through a study of those physical proper- ties that can be readily seen or easily measured. With soil surveys, many interpretations can be ma about the behavior of the soils under certain use or systems of management. Predictions can be mad about the suitability of the soils for selected uses and about management requirements.

4/Lytle, S. A. The Morphological Characteristics and Relief Relationships of Representative Soils in Louisiana. Bulletin No. 631. La Agric. Exp. Station; 1968. 21 p.

Vegetative Analysis in the Loblolly Pine - Shortleaf Pine - Upland Hardwood Forest Type, Louisiana

Donald P. Reed[1] and Robert E. Noble[2]

Abstract.--Vegetative yield was measured on the Catahoula District of the Kisatchie National Forest near Dry Prong, Louisiana during 1979 and 1980. Results were compared with different soil types, stand types, stand ages, basal areas, and canopy covers. Canopy cover was the most significant variable affecting understory vegetative yield, followed by basal area. As available sunlight decreased, understory vegetative yield also decreased.

INTRODUCTION

Cattle grazing on portions of the South's National Forests has long been a controversy between cattlemen, foresters, wildlife biologists, environmental organizations, and other groups pushing for their favored use of a public resource. The purpose of this study was to obtain quantitative data on forage production of a particular area. This may assure the best possible use of a public area within the framework of a "multiple use" concept. In obtaining these forage production figures, an inventory was made of the plant composition on the area. The major objective of the study was to show how plant composition and forage production were affected by soil type, stand type, and stand age.

STUDY AREA

The loblolly pine-shortleaf pine-upland hardwood forest type studied is located on the Catahoula District of the Kisatchie National Forest, Grant Parish, Louisiana. The study area comprised approximately 8,000 acres.

Overstory vegetation consisted of the pine-upland hardwood forest type with scattered streambottom hardwoods. Hardwoods comprised 47% of the total basal area. The establishment of pine plantations with hardwood removal and prescribed burning, influenced the vegetative composition on certain areas. The following stand ages were recognized on the study area, along with their respective percentages of the total area.

Stand types:
1. No forest 2.9%
2. Upland hardwoods 1.3%
3. Stream-bottom hardwoods 1.3%
4. Loblolly, shortleaf pine, upland hardwoods 94.5%

Stand ages:
1. Non-stocked (no timber present) 2.9%
2. Seedlings (trees less than 3 years old) 4.3%
3. Saplings (trees greater than 3 years old and less than 4 in. dbh) 13.4%
4. Poles (trees between 4 in. and 9 in. dbh) 23.2%
5. Sawtimber (trees greater than 9 in. dbh) 56.2%

METHODS AND PROCEDURES

Sampling Design and Intensity

Vegetative measurements were carried out around 1000 permanent sample plot centers. Plots were placed along 37.8 miles of transect lines, and were 200 ft. apart. Transect lines were drawn on 15 minute series quadrangle maps and then reproduced in the field as accurately as possible using a hand-held compass. Each plot center was monumented with a steel reinforcement rod and a plastic yellow flag attached to a stiff wire. The plot centers served in the following measurements:

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Understory Vegetative Clipping.--Forage yield was determined by using the clipping method described by Cook et al. (1962). Frames used to delineate the clipping area were 3.12 ft. sq. and were constructed by bending number 10 gauge steel wire. The frames were placed 9 ft. from plot center to avoid biasing future vegetative cover estimates. Frames were placed in a different compass direction around the plot center each time clipping was carried out. This allowed an undisturbed area to be clipped each time. All understory greenery constituting the current years growth was removed from ground level to a height of 6 ft. Vegetative plant material was dried for 48 hours at 100°C and weights were recorded to the nearest 0.01 gram by using a Mettler P 1210 balance scale. The number of plots sampled during each phase of understory vegetative clipping was:

Spring 1979:	206
Summer 1979:	256
Spring 1980:	145
Summer 1980:	265

Collection of understory vegetative biomass samples for 1979 began on April 28th and ended on November 4th. In 1980, data collections ran from May 3rd to October 12th. During both years, sampling began after the spring greenup and ended before the first frost.

Overstory Tree Measurements.--Overstory vegetation, (4 in. dbh and greater), was sampled in 0.1 acre circular plots. Dbh was measured with a tree caliper. The height and age of a representative dominant and co-dominant tree (where applicable) were recorded for pines and hardwoods. Heights were taken with a Suunto clinometer and ages were determined with an increment borer. The number of snags (a dead tree at least 10 ft. tall and 10 in. dbh) was recorded. Percent overhead canopy cover was estimated for each plot.

Middlestory Vegetative Measurements.--Regeneration (trees and shrubs less than 4 in. dbh and taller than 6 ft.) was sampled in 0.25 acre circular plots. The number of stems of pines, hardwoods, and shrubs, was recorded. Any woody perennial plant, characterized by a low growing posture and branching from the base, was classified as a shrub. Overstory tree measurements and regeneration data were collected at 501 plot locations.

Taxonomic Nomenclature and Data Analysis.--The taxonomic nomenclature of plants is from Radford et al. (1968). A regression equation was used to illustrate the differences in vegetative yield brought about by altering basa areas between pines and hardwoods. An analysis of covariance showed the importance of canopy cover, soil type, stand type, and stand age on understory vegetative yield.

RESULTS AND DISCUSSION

Overstory and Middlestory

The amount of understory vegetative biomas in lbs/ac produced under the various stand ages was:

stand age	highest yield	lowest yield	averag yield
seedlings	1957	78	688
saplings	783	39	412
poles	380	11	134
sawtimber	507	2	178

The percent overhead canopy closure of a stand had the greatest effect on understory vegetative yield (Table 1). As canopy closure

Table 1. Analysis of covariance, with dependen variable being understory vegetative yield in lbs./ac., Dry Prong vegetative yield study

Source of variation	Degrees of Freedom	Sums of squares	F Value	Probability [1]
Canopy	1	13597.79	333.07	0.0001
Soil type	9	965.22	2.63	0.0054
Stand type	7	762.85	2.67	0.0099
Stand age	4	592.01	3.63	0.0061

[1] Values less than 0.05 are significantly different.

ncreased, vegetative yield decreased. The ide-spreading crowns of hardwood trees enerally shaded a larger area than pine trees f equal basal area. As illustrated in Table 2, 143 lbs of understory vegetative biomass can be produced by shifting basal areas of a stand from hardwoods to pines. Overstory and middlestory characteristics on the study area are presented in Table 3.

able 2.--Regression equation for predicted nderstory vegetative yield, based on contrived ardwood and pine basal areas

asal area ardwoods q. ft./ac.	Basal area pines sq. ft./ac.	Vegetative yield lbs./ac.
10	90	195
90	10	52
25	75	161
75	25	72
50	50	112
0	25	452
25	0	367
30	60	172
35	70	131
25	70	172

Browse and Herbage

In 1979, understory vegetative biomass on the study area was 321 lbs/ac during the spring (greenup through May 31) and 315 lbs/ac during the summer (June 1 until first frost). A drier year in 1980 caused understory vegetative weights to be significantly different. During spring and summer 1980, understory vegetative biomass was 237 lbs/ac and 268 lbs/ac, respectively. Rainfall amounts[1] in 1979 totalled 74.28 inches as compared to 55.62 inches in 1980. As indicated in Table 4, the majority of the vegetative biomass produced came from woody plants. Quercus spp. was the number one woody plant in terms of understory vegetative biomass production and was second behind only Andropogon spp. as the top biomass producer (Table 5).

Table 3.--Characteristics of Stand Types and Stand Ages, Dry Prong Vegetative Yield Study

	Stand Type									
	No Forest	Loblolly-Shortleaf Pine-Upland Hardwoods				Upland Hardwoods			Stream bottom	
Characteristics	non-stocked	seedlings	saplings	poles	sawtimber	saplings	poles	saw-timber	poles	saw-timber
% canopy cover	c[1/]	10	16	53	55	5	60	48	95	50
basal area pines[2/]	c	30	16	46	68	0	2	3	1	0
basal area hardwoods	c	4	17	28	31	12	68	65	89	68
no. snags/ac.	0.14	0	0.12	0.15	0.08	0	0	0.5	1.0	0.4
ht. dominant hardwoods[3/]	c	20	45	43	54	44	60	50	58	72
ht. co-dominant hardwoods	c	c	51	37	50	c	72	41	32	54
ht. dominant pine	c	52	46	43	73	c	42	38	c	c
ht. codominant pine	c	c	70	44	64	c	c	c	c	c
age dominant hardwoods[4/]	c	27	40	43	50	39	59	53	58	62
age co-dominant hardwood	c	c	40	29	46	c	58	37	25	38
age dominant pine	c	38	29	25	45	c	21	34	c	c
age co-dominant pine	c	c	28	23	39	c	c	c	c	c
pine regeneration stems/ac.	3	340	704	241	159	40	0	0	40	0
hardwood regeneration stems/ac.	114	360	977	747	662	960	980	980	1120	808

[1/] condition does not exist for that situation.

[2/] basal area in ft.^{2} per acre.

[3/] height in feet.

[4/] age in years.

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[1] Rainfall data taken from Alexandria weather station located 20 miles south of study area.

Table 4.--Understory Vegetative Biomass in lbs./ac. by Season of Clipping and Life Form, Dry Prong Vegetative Yield Study

	Season			
Life Form	Spring 1979	Summer 1979	Spring 1980	Summer 1980
Woody	197	152	139	160
Forbs	12	25	10	15
Grass	51	99	37	48
Vines	53	36	50	43
Legumes	4	1	1	1
All of the above which made up less than 0.01 lbs./ac.	4	2	0	1
TOTAL	321	315	237	268

Synthesis

Control over canopy closure is the key factor influencing understory vegetative yie In areas where sunlight was able to reach th ground, increased amounts of vegetative bioma was produced. Both annuals and perennials benefited from the increased levels of sunlig Canopy closure is influenced by basal area composition (hardwoods vs. pines) and amount. Basal area composition can be controlled by selectively cutting pines or hardwoods, while basal area amount is influenced by the stocki and age of the stand. Rainfall amounts influenced vegetative yield during the two ye the study was conducted.

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Radford, A. E.; Ahles, H. E.; Bell, C. R. Manual of the vascular flora of the Carolinas. Chapel Hill, N.C.: Univ. of North Carolina Press; 1968. 1183p.

Table 5.--Major Species[1] Contributing to the Total Vegetative Biomass by each Season of Clipping, Dry Prong Vegetative Yield Study

	Vegetative Biomass lbs./ac.					
Taxon	Spring 1979	Summer 1979	1979 avg.	Spring 1980	Summer 1980	1980 avg.
Andropogon spp.	22.92	47.22	35.07	15.95	27.49	21.72
Quercus spp.	24.99	29.92	27.45	13.92	34.73	24.32
Myrica cerifera	22.56	20.01	21.28	8.97	21.14	15.05
Cornus florida	24.20	16.45	20.32	15.88	13.22	14.55
Vaccinium spp.	20.71	16.70	18.71	10.99	19.26	15.12
Gelsemium sempervirens	15.27	15.84	15.56	7.32	18.50	12.91
Acer rubrum	17.65	9.94	13.80	20.10	9.19	14.65
Panicum spp.	12.52	20.76	16.64	8.60	4.76	6.68
Vitus rotundifolia	13.98	5.90	9.94	16.79	10.02	13.40
Liquidambar styraciflua	12.75	10.75	11.75	12.33	9.68	11.01
Rubus spp.	17.19	8.20	12.69	13.11	6.45	9.78
Pinus spp.	13.83	13.57	13.70	2.75	10.31	6.53

[1] A taxon was considered major if the average biomass produced during 1979 and 1980 was 10 lbs./ac. or greater.

AMPHIBIANS AND REPTILES OF LOBLOLLY-SHORTLEAF PINE STANDS IN CENTRAL LOUISIANA

Kenneth L. Williams and Keith Mullin

Abstract.--Amphibian and reptile species composition and abundance were surveyed on four study sites, each 2000 acres, on the Catahoula Ranger District, Kisatchie National Forest, in central Louisiana, from August 1979 to May 1981. Four stand size classes (habitats) were sampled within each study area--regeneration, sapling, poletimber, and sawtimber. A variety of census methods were used, including walking transects and fence arrays with pitfalls and funnel traps. Sawtimber exhibited the most herpetofauna diversity. Amphibians were not abundant in any stand type. Reptiles were more abundant, but with the exception of three species of lizards, probably not abundant enough to serve as good indicators of habitat change resulting from grazing.

INTRODUCTION

Catahoula Ranger District, Kisatchie National rest, is located in Louisiana in Grant Parish, in e vicinity of Dry Prong. The study sites consist four fenced areas of approximately 2000 acres ch.

The area is generally described as loblolly-ortleaf pine, with loblolly distinctly dominant. ed (1981) in his analysis of the vegetation, dicated that the basal area consisted of 47% rdwoods. Loblolly is considered to be more ade tolerant than other pines of this area. is factor may account for the large percent of rdwoods (Shelford, 1963). The soil of this udy area is presented in a detailed publication the U.S. Department of Agriculture (1979, for ant Parish).

The two major objectives of this study were:

. To determine the kinds of amphibians and reptiles in the four stand types.
. To obtain quantitative data for each stand type, which could be utilized in later phases of the study.

e overall purpose was to obtain data fulfilling ese objectives and then utilize these data in ter studies to evaluate the effect of cattle azing on herpetofauna occurrence and abundance.

Due to United States Forest Service timber nagement practices the forest is in various ages of development ranging from clearcut areas varying sizes up through mature pine stands. r sampling purposes four stand size classes were recognized:

1. regeneration: "recently site prepared, with or without pine seedlings.
2. Saplings: trees up to 4 inches dbh.
3. Poletimber: trees from 4 inches to 10 inches dbh.
4. Sawtimber: trees 10 inches or more dbh, most would be classified as immature sawtimber.

Amphibians and reptiles are common animals of this area of Louisiana. Within this area piney woods are probably the least desirable habitat for many amphibians and reptiles (see the list below species that occur/or may occur in the region of Louisiana where the study sites are located). The numbers following each species in the list are: 1=obtained in study, 2=known to occur in similar habitat locally, but not obtained in present study, 3=not recorded from general area, but very likely occurs, and 4=range maps show it occurring in this area, but not likely due to lack of suitable habitat.

Species (Amphibia)	Category
Siren intermedia	3
Amphiuma tridactylum	4
Necturus beyeri	4
Notophthlamus viridescens	3
Ambystoma talpoideum	3
Ambystoma texanum	3
Ambystoma maculatum	3
Ambystoma opacum	1
Desmognathus auriculatum	3

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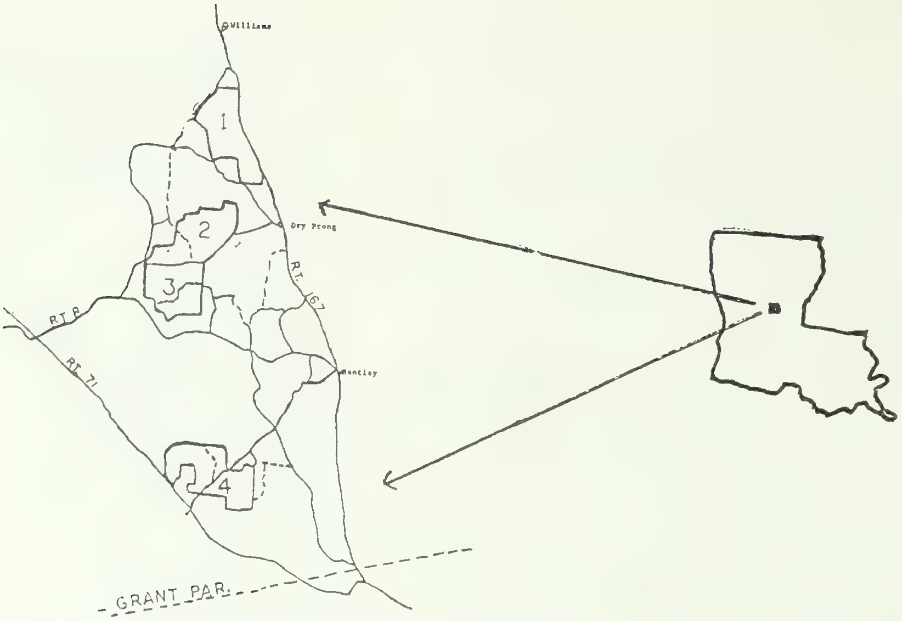

Figure 1. Location of the Catahoula Ranger District study sites, Grant Parish, Louisiana. (Scale one-fourth inch=one mile)

Species	Category
Plethodon glutinosus	4
Eurycea quadridigitata	1
Scaphiopus holbrooki	3
Gastrophryne carolinensis	1
Bufo woodhousei	1
Bufo valliceps	1
Hyla crucifer	1
Hyla cinerea	1
Hyla versicolor	1
Hyla squirella	3
Pseudacris triseriata	2
Acris crepitans	1
Rana clamitans	1
Rana catesbeiana	4
Rana sphenocephala	1
Rana areolata	4

Species (Reptilia)	Category
Alligator mississippiensis	4
Macroclemys temmincki	4
Chelydra serpentina	2
Sternotherus odoratus	3
Sternotherus carinatus	4
Kinosternon subrubrum	3
Graptemys pseudogeographica	4
Graptemys kohni	4
Chrysemys concinna	4
Chrysemys floridana	4
Chrysemys scripta	4
Chrysemys picta	4
Deirochelys reticularis	4
Terrapene carolina	1
Trionyx muticus	4
Trionyx spinifer	4
Anolis carolinensis	1
Sceloporus undulatus	1
Scincella lateralis	1
Species	Category
Eumeces fasciatus	1
Eumeces laticeps	1
Eumeces anthracinus	1
Cnemidophorus sexlineatus	1
Ophiosaurus attenuatus	3
Nerodia erythrogaster	4
Nerodia rhombifera	4
Nerodia cyclopion	4
Regina rigida	4
Regina grahami	1
Thamnophis sirtalis	3
Thamnophis proximus	4
Virginia striatula	3
Storeria dekayi	1
Storeria occipitomaculata	3
Heterodon platyrhinos	1
Diadophis punctatus	1
Opheodrys aestivus	1
Farancia abacura	4
Coluber constrictor	1
Masticophis flagellum	1
Pituophis melanoleucus	3
Elaphe obsoleta	1
Elaphe guttata	3
Cemophora coccinea	3
Lampropeltis triangulum	3
Lampropeltis calligaster	3
Lampropeltis getulus	1
Tantilla gracilis	3
Agkistrodon piscivorus	1
Agkistrodon contortrix	1
Sistrurus miliarius	3
Crotalus horridus	3
Micrurus fulvius	1

When hardwoods are allowed to develop along creek bottoms providing more diversity, kinds a numbers of organisms, including amphibians and iles increase. However, as this study indicates y woods can sustain a moderate variety of ibians and reptiles, and in a few cases sub- tial populations. Some of the species recorded in are dependant upon the small sources of r in the area.

Amphibians and reptiles are basically second hird level consumers in the food chain. They ly are important links in the food web of the y woods studied.

METHODS AND PROCEDURES

Straight line transects were established and ed. Shrubs and trees (6 ft. or lower) were cked for herpetofauna (especially the lizards lis and *Sceloporus*), and ground cover was ched, especially for the lizards *Scincella* and midophorus. In addition debris (logs mainly) hin 10 yards on either side of the transect e rolled over or if rotten "pulled apart" and rched for herpetofauna.

Each transect was located within a specific itat type and was searched for a recorded unt of time. A compass was used to maintain a aight line.

The other primary method used was a drift ce with associated five gallon buckets (sunk in 1) and funnel traps (Campbell and Christman, 2; see Williams and Mullin, 1987 for diagram). traps were randomly established in each of the itat types and maintained throughout the study.

Other census methods were occasionaly used h varying success. However, they did allow addition of several species that would not e been otherwise recorded. These methods were:

. Accidental observation while moving through the area, often from one trap site to another.
2. Driving the roads at night during warmer months. When a specimen was discovered in this manner, the type of habitat closest was recorded.
3. At the beginning of the study, quadrats were randomly set up and walked for a set amount of time. This procedure was discontinued and the transect method (discribed above) was substituted. The time involved in establishing randomly located quadrats was prohibitive.

The study sites were visited an average of ice a month. Usually one or two days were spent the site each trip. During cold weather the isits were less frequent. Visits were made by e or both of the authors.

Sawtimber was the most abundant habitat; pling stands were second in abundance. Pole- imber and regeneration habitats were less available. nsequently, sampling by necessity, were greater sawtimber and sapling stands. For all comparisons given here, data are expressed as mean/ unit effort (i.e., number per trap night or per hour searched).

We used Conant (1975) and occasionaly Keiser and Wilson (1979) for species identification. Nomenclature follows Conant (1975) except for watersnakes, where *Nerodia* was used instead of *Natrix*.

RESULTS AND DISCUSSION

The amphibians collected indicate a moderately diverse group of species (Table 1). They are most abundant in sawtimber, uncommon in poletimber, and virtually absent in sapling and regeneration. Factors that may account for this are: 1)presence or absence of water, and 2) shaded cover. Both factors were most frequent in sawtimber. Also certain species were only/or more frequently encountered where transects crossed creeks.

Table 1. Number of amphibians trapped or encounted (parenthesis value).

Species	Sawtimber[1]	Pole[1]	Sapling[1]	Regeneration[2]
Ambystoma opacum	1(4)	0(0)	0(0)	0(0)
Eurycea quadridigitata	2(4)	1(1)	1(0)	0(0)
Bufo woodhousei	8(2)	2(3)	1(0)	0(0)
Bufo valliceps	1(0)	0(0)	0(0)	0(0)
Gastrophryne carolinensis	6(4)	3(0)	9(0)	0(0)
Acris crepitans	0(2)	0(0)	0(0)	0(0)
Hyla cinerea	0(1)	0(0)	0(0)	0(0)
Hyla crucifer	0(2)	0(0)	0(0)	0(0)
Hyla versicolor	1(3)	0(0)	0(0)	0(0)
Rana spenocephala	4(7)	0(1)	0(0)	0(0)
Rana clamitans	0(4)	0(0)	0(0)	0(0)
"frogs"	5(0)	0(0)	1(0)	0(0)
Totals	28(33)	6(5)	12(0)	0(0)

[1] The data for trapping results represents the totals for 104 trap nights. The data for transect walks represents 60 hours total time.

[2] The data for trapping results represents the totals for 68 trap nights. The data for transect walks represents 30 hours total time.

Reptiles (Table 2) were more numerous and in most cases less restricted to water or wet situations. Thus, they are of more potential use as indicators of habitat disturbance.

Regeneration appears to be virtually sterile. Sapling and poles when trap and transect results are combined appear rather similar but still with sparce populations. Sawtimber shows greater diversity in both trap and transect results.

Lizards were the most abundant reptile group. The three lizard species exhibiting obserable abundance were the fence lizard (*Sceloporus undulatus*), the ground skink (*Scincella lateralis*), and the American anole (*Anolis carolinensis*) (Table 3). Although *Anolis carolinensis* and *Sceloporus undulatus* are found in all habitat types, in sapling and regeneration many records, especially Anolis, were obtained as transects passed near isolated hardwoods (often black-jack oak).

Table 2. Number of reptiles trapped or encounted (parenthesis value).

Species	Sawtimber[1]	Pole[1]	Sapling[1]	Regeneration[2]
Terrapene carolina	5(3)	6(1)	8(1)	0(0)
Anolis carolinensis	6(2)	2(4)	1(6)	0(1)
Sceloporus undulatus	17(14)	3(6)	1(7)	0(1)
Scincella lateralis	21(28)	7(13)	2(0)	0(1)
Eumeces fasciatus	2(4)	0(0)	0(0)	0(0)
Eumeces anthracinus	2(1)	0(0)	0(0)	0(0)
Cnemidophorus sexlineatus	0(1)	0(1)	0(0)	0(0)
Coluber constrictor	0(0)	1(2)	0(2)	0(2)
Diadophis punctatus	1(0)	0(0)	0(0)	0(0)
Elaphe obsoleta	0(1)	0(1)	0(2)	0(0)
Masticophis flagellum	0(2)	0(0)	0(0)	0(0)
Opheodrys aestivus	0(1)	0(0)	0(0)	0(0)
Lampropeltis getulus	0(0)	0(0)	0(1)	0(0)
Storeria dekayi	1(4)	0(1)	1(0)	0(0)
Heterodon platyrhinos	0(0)	2(0)	0(0)	0(0)
Regina grahami	0(1)	0(0)	0(0)	0(0)
Agkistrodon contortrix	1(5)	0(1)	1(0)	0(0)
Agkistrodon piscivorus	0(7)	0(0)	0(0)	0(0)
Sistrurus miliarius	1(2)	0(1)	0(0)	0(0)
Micrurus fulvius	1(0)	0(0)	0(0)	0(0)
Totals	57(76)	21(31)	13(16)	0(5)

[1] The data for trapping results represents the totals for 104 trap nights. The data for transect walks represents 60 hours total time.

[2] The data for trapping results represents the totals for 68 trap nights. The data for transect walks represents 30 hours total time

Comparisons between the results given here and Vernon Ranger District results are presented in Williams and Mullin (1987).

Table 3. Occurrence(%) of the three most common lizards by stand size class.

Species	Sawtimber	Poles	Saplings	Regener.
Anolis	33	29	33	05
Scincella	68	28	03	01
Sceloporus	62	19	17	02

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Mammalian use of Habitat in the Loblolly-Shortleaf Pine Type of Louisiana

Robert B. Hamilton, Steven W. Ellsworth, and Joe Clint Smith

Abstract.--Indices of mammalian abundance were obtained for 26 species on four study areas. Small mammals were snap-trapped along vegetation transects and differed in habitat preferences. Larger mammals were sampled with scent-posts, night-light, and track counts. Indices differed by area and season. Suggestions are made for future sampling.

INTRODUCTION

Because of recent controversy over grazing n some southern national forests, a Southern ange Evaluation Project was begun in 1978 on two orest types in four southern states to evaluate he effects of grazing. Baseline data on the reltive abundances of mammalian species at specific razing levels are needed if the effects of grazng are to be evaluated. This study was designed o provide such data for ungrazed national forests f central Louisiana. The data gathered will be nalyzed with respect to study area because future reatments will be on a study area basis.

The relative efficiency of the many techiques available for assessing abundance of free-anging mammals is not well known. Because wild ammals are primarily nocturnal and often cannot e observed easily, many of the techniques do not equire direct observation. Mammals vary greatly n size, behavior, and means of locomotion and, herefore, there is variation in the applicability f techniques among species. In addition, some ammalian sampling is destructive and can al+ter bundance. It is not clear which techniques will rovide the most reliable indices for various pecies of mammals or what sample sizes are equired to provide a reliable index. We will ealuate the techniques we used to determine mamalian abundance in this paper, in addition to eporting the relative abundance indices that we btained. We will also attempt to determine the aximum sampling intensity required in the future n order to detect a 20% change in abundance on an rea.

Our specific objectives in this study are to .) determine the species present and their abunlances in different habitats, study areas, and easons. 2) evaluate the techniques used as to ffectiveness for various species. 3) determine he sampling intensity required to detect a 20% hange in abundance if variance of the new sample s no greater than the variance of our combined data set (This is almost a worst case condition.), and 4) determine the habitat preferences of the small mammals that are present on the study areas.

We want to thank all those who helped to make this study possible. The field work was financed by the U.S. Department of Agriculture, Forest Service, the LSU Agricultural Center and Louisiana Agricultural Experiment Station. Most of this work was performed by Steve Ellsworth and Clint Smith and the data were used in their M.S. Theses. We were aided in the field by students, Lloyd Mitchell, Gary Lester, Robert Abernathy, Bill Hickman, and Kathy Fouchi. Dr. Robert Noble and Don Reed helped with vegetation analysis and set up the vegetation transects that we used. Drs. Nancy Keith, James Geaghan and Vernon Wright helped with the statistical analysis. We appreciate the help we received from Forest Service employees, especially Dr. Henry Pearson. The Louisiana Department of Wildlife and Fisheries provided living quarters near the study area.

STUDY AREA

Field work was conducted on the same four study areas in the Catahoula Ranger District of the Kisatchie National Forest that are described elsewhere in this publication (see Hamilton and Lester 1987). Differences in detail between the studies will be discussed, where appropriate.

Sampling Areas

Small mammal trapping was primarily conducted along the existing vegetation sampling lines described by Reed (1981). He identified five stand ages based on age or dbh of dominant trees. Age frequencies varied greatly among study areas (tab. 1). "Sawtimber", with a low of 40.3% on Area 1 and a high of 76.7% on Area 4, was the most frequently occurring age on each of the study areas.

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Stand Types

Reed (1981) classified the vegetation into eight stand types. We used six of these types because his distinctions were finer than necessary for mammal sampling and we had difficulty at times obtaining sufficient sample sizes. His "loblolly-shortleaf-occasional longleaf pine forest"[1] and "longleaf pine" types were combined into "pure pine" and his "loblolly-shortleaf pine-upland hardwood" and "loblolly-shortleaf-longleaf pine-upland hardwood" were combined into "pine-upland hardwood". The relative proportions of these types varied considerably among the study areas (tab. 2).

Table 1.-- Relative frequency of occurrence (%) of forest stand ages in each study area, 1980

Stand Age[1]	Area 1	2	3	4	1-4
Unstocked	0.7	0.4	0.0	11.5	2.9
Seedlings	0.7	17.0	0.0	0.0	4.3
Saplings	18.3	8.3	24.5	0.9	13.4
Poles	40.3	29.5	7.2	11.0	23.2
Sawtimber	40.0	44.8	68.3	76.6	56.2

[1] Stand ages follow Reed (1981:12).

Table 2.-- Relative frequency of occurrence (%) of forest stand types in each study area, 1980

Stand Type	Area 1	2	3	4	1-4
Unstocked	0.3	0.0	0.0	11.5	2.9
Pine-UpHard	82.0	40.3	70.5	50.2	60.7
Pine StHard	6.4	8.3	21.9	3.5	10.0
Upl. Hard.	0.3	3.3	1.3	0.4	1.3
Pure Pine	9.5	47.7	4.6	32.6	23.6
Stream. Hard.	1.4	0.4	1.7	1.8	1.3

Ecological Description

The boundaries between the habitats were relatively sharp. Although some of the more inaccessible parts of the study areas held uneven-aged stands, many large (50-200 ac), even-aged blocks, of various ages were present.

Management

The study areas had once been used as open range for cattle and hogs, but there has been no legal grazing on the study areas for the 20 years prior to the study. The forest is presently managed for timber and pulp production. Clearcutting and prescribed burning are extensively practiced. Regeneration is often by the seed tree methoc by planting.

METHODS AND PROCEDURES

Because the many different combinations f stand types and ages present could not all be a quately sampled with the resources available d the different types of mammals expected to e present could not all be sampled the same way, e used procedures designed to maximize the rate f data collection from various groups for the eff involved. We accomplished this by collecting d along transect lines rather than in scatte plots and thereby used our time efficiently. chose methods that minimized transportation dif culties by placing plots along existing trans lines, trails, or roads. We gathered data at times of maximum availability or when the expec rate of data acquisition would be near a maxim There were projects on both birds and mammals a those responsible for data gathering for b groups helped each other as much as possible (example, much of the bird work was done in t mornings and much of the mammal work was done the afternoon by all the people involved). In a dition, we gathered as much data as possible at between the existing vegetation sampling points as to minimize the amount of vegetation sampli required for habitat description.

Methods were chosen that were repeatable a would provide reliable indices of abundance. O taining absolute abundance information would ha been almost impossible for any species on t study areas and such information was not requir for the purposes of the study.

Sampling Procedures

Mammals were detected through the use scent posts, snap traps, predator calls, and nig lights. We also counted tracks, counted squirr leaf nests, and shot bats.

Indices of mammalian abundance by area, sea son, stand type, and stand age with standard er rors and coefficients of variation were prepare when sample sizes were sufficient. Comparisons between the various indices of mammal abundance were made with Chi-square tests or ANOVA. Where differences were found with ANOVA, Duncan's Multiple Range Test was used to ascertain the treatment(s) where the differences in index occurred.

When possible, we calculated the sampl sizes required in the future to determine a 20 change in mammal numbers for the groups we studied. For these calculations we assumed th variance of the future sample would be the same a the variance we obtained in this study. Th variances we used in these calculations wer obtained from the entire data set (results fro different for each group and consequently th variances we used were relatively high.

In addition, the effects of habitat vari ables on small mammal occurrence were tested wit

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[1] See Reed (1981) for type descriptions.

NOVA and Duncan's Multiple Range Test to ascer- ain which species was (were) significantly dif- erent with respect to the variables. Calcula- ons were performed using programs of the Statis- ical Analysis System (SAS) (Helwig & Council 979) on an IBM 3033 computer at the Systems Net- ork Computer Center, Louisiana State University. o evaluate the importance of these variables, a tepwise Discriminant Analysis was performed with ograms from the Statistical Package for the So- ial Sciences (SPSS) (Nie et al. 1975). Redundant ariables were removed from the analysis based on he results of a correlational analysis.

An alpha level of 0.05 was used for all ests.

ield Methods

Small Mammals.--The existing vegetation ransects formed modified Calhoun Lines (Linn 963). Trapping along the transects was done wice, primarily on week-ends, from October 1979 o June 1980, and continued from November 1980 ntil June 1981. Trapping success was negligible n the heat of summer.

When trapping along the transect, we placed ive museum special traps, baited with peanut but- er, at places we judged to be the most likely pots for small mammal use within 40 ft of plot enters. Each trap had been modified by stretch- ng a wire midway across the trap bar to facili- ate catch of smaller species. Traps were set for night and moved. Captured animals were prepared s museum specimens and placed in the Louisiana tate University, Museum of Natural Science.

Large mammals.--Indices of abundance of arge mammals were prepared by study area. Sam- ling by habitat type was impractical and probably ot meaningful because the home ranges of many of he mammals were large enough to include several djacent habitat types.

cent Post Counts

Twenty, permanent, 1.0-m diameter circular rack stations were placed near abandoned logging oads in each of the four study areas at 0.2-mi ntervals (see Linhart and Knowlton 1975). tation locations are indicated in Ellsworth 1983:173-176). Surface vegetation was removed rior to sampling, track beds were brushed clean, olomitic limestone was spread evenly, and a apsule containing 1 ml of attractant (synthetic atty acid scent; Bullard et al. 1978a, 1978b, oughton and Sweeny 1982) was applied prior to the irst day of a 3-day trapping period. We nitially attempted to make a track surface by aking the soil but most tracks were not iscernible. The clay soils on the area would not ake a track from relatively light animals and ome of the loamy soils became powdery and lost heir ability to hold tracks in dry weather. The imestone made a better track surface, especially hen the soil beneath it was hard. Morrison 1981) had more responses of rabbits (*Sylvilagus* spp)[2] and coyotes (*Canis latrans*) with limestone than with natural soils. When the stations were checked after the first and second night, responses were recorded at each station by species or species group (where individual species could not be differentiated, such as for rabbits, data were recorded as a species group), the tracking surface was refurbished, and 0.5 ml of attractant was added. After the third night, only data were recorded. Lines were run 6 times, once every 3 months, from 1 Apr. 1980 to 20 Jul. 1981.

Spot-lighting

Standardized survey routes along suitable roads were selected in Areas 1-3 (Ellsworth 1983:181-2). No suitable roads existed in Area 4. The routes were sampled, at least once/month, when possible, except July and September, by two observers (driver and passenger) at night, beginning between sunset and 1 hr. past by driving slowly (10-12 mph) and scanning both sides of the road with a 200,000 candlepower "Q-beam" spotlight. Animals seen by the driver or passenger were recorded by area and road. Surveys were done from Oct. 1979 until May 1981.

Track Counts

Monthly track counts were made along all suitable gravel roads on areas 1-3 (Ellsworth 1983:183-184). We walked up one side of a road and down another, preferably 2 days after a rain, and counted all tracks.

Other methods

Squirrel leaf-nest counts, bat shooting, and predator call counts were also made (see Ellsworth 1983), but detailed results will not be reported here.

RESULTS

Weather

Weather patterns may have differed slightly from long term averages (tab. 3). but patterns of mammalian abundance prior to our study are not known and it is impossible to evaluate weather effects on abundance data. However, there was a draught in the summer of 1981 that prevented track formation and interfered with data gathering.

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[2] Common and Scientific names are from Lowery (1974).

Table 3.-- Some climatological data for overall study area[1], January 1980 to June 1981 with 20 year averages (1951-1973) recorded at Winnfield, 18 mi north of Area 1 (from Ruffner 1979)

	Mean Max.Daily Temp (°F)		Mean Min.Daily Temp (°F)		Tot.monthly precip. (in)	
Mon.	20-yr	80/81	20-yr	80/81	20-yr	80/81
Jan	59.2	60.6	36.3	39.9	4.5	5.0
	"	57.9	"	34.0	"	1.8
Feb	63.0	64.6	38.5	38.7	4.6	4.4
	"	60.4	"	41.2	"	3.3
Mar	70.3	68.2	44.4	44.8	4.8	10.6
	"	68.5	"	43.2	"	5.4
Apr	78.8	77.2[2]	52.0	47.7[2]	5.2	3.3
	"	78.6	"	56.5	"	1.0
May	84.7	82.8	60.4	62.4	6.1	6.6
	"	79.3	"	59.2	"	6.8
Jun	90.9	91.2	67.5	70.0	3.6	4.4
	"	90.1[3]	"	71.8[3]	"	6.6
Jul	93.0	96.6	70.2	72.5	5.4	1.5
Aug	93.0	95.9	69.1	69.6	3.3	1.5
Sep	88.7	93.9	64.0	67.6	4.7	6.4
Oct	79.9	77.9	52.2	49.1	2.6	6.4
Nov	68.5	66.6	43.0	41.7	4.1	4.2
Dec	60.8	62.4	37.8	38.8	5.4	0.5

[1] Recorded ca. 8.8 km (5.5 mi) northeast of Area 4, at the Catahoula Forest, Catahoula Ranger District, Kisatchie National Forest (pers. comm. Mr. Charles Turner, climatologist, USDA Forest Service, Kisatchie National Forest, Pineville, Louisiana.)

[2] 5 days of data missing.

[3] 3 days of data missing.

Snap-trapping.--Golden mice (*Ochrotomys nuttalli*)2, cotton mice (*Peromyscus gossypinus*), short-tailed shrews (*Blarina brevicauda*), fulvous harvest mice (*Reithrodontomys fulvescens*), and white-footed mice (*Peromyscus leucopus*) were the most frequently captured species (tab. 4). The Least shrew (*Cryptotis parva*) and the cotton rat (*Sigmodon hispidus*) were not caught enough for analysis.

Table 4.-- Abundance indices (number caught/ trap-nights) and sample sizes (S. needed to detect a 20% change in d sity calculated from 9070 trap-nig for the entire area, 1979-1981

	Statistics			
Species	caught	index	S.E.	S.
Cotton mouse	150	1.65	0.15	6,7
Wh-ft. mouse	49	0.54	0.10	29,8
Golden mouse	158	1.74	0.15	6,4
F. ha. mouse	53	0.58	0.09	19,1
Sh-tl. shrew	107	1.18	0.11	7,9
Least shrew	2	0.02	0.02	
H. cotton rat	4	0.04	0.02	

Total catch of all small mammals varied w forest stand type (tab. 5). Trap success was most 50% better in the "non-forested" area (10. than any of the forested ones. In forests, tot trap success varied from a low of 5.5% in t "pine-upland hardwoods" to 7.1% in the "pi streambottom hardwoods". Standard errors other statistics can be found in Ellswor (1983:141-146).

Table 5.-- Abundance indices (number caught/1 trap nights) of small mammals by sta type, 1979-1981

	Stand Type[1]					
	Z	P	PU	PS	U	
Cotton mouse	5.6	0.9	1.5	3.3	4.2	4
Wh-ft. mouse	2.6	1.2	0.3	0.0	0.0	0
Golden mouse	0.0	1.7	2.0	0.8	1.7	1
F. ha. mouse	0.5	1.3	0.4	0.0	0.0	0
Sh-tl. shrew	1.0	1.4	1.0	1.3	0.0	1
All[2]	10.3	6.8	5.5	7.1	5.8	6
Trap-nights	195	2460	5355	840	120	1

[1] Z = unforested, P = pine, PU = Pine-Upland Har woods, U = Upland Hardwoods, S = Streambott Hardwoods.

[2] All = Total for all small mammals.

Small mammals were caught more in t younger aged stands. Short-tailed shrews we caught almost equally in all of the older stan as were golden mice (tab. 6). Standard errors a other statistics are in Ellsworth (1983:147-151)

We tested stand type and stand age prefe ence with a "suitability index", the percenta caught in a habitat divided by the percentage trap nights in the habitat times 10. Use of thi index allows comparisons of habitat importance among species. An index value of 10 represent random distribution. "Seedling" and "sapling ges were preferred by four of the five species or which we have data (tab. 7).

"Pine" and "unforested" were preferred by hree and two species, respectively (tab. 8).

able 6.-- Snap-trap abundance indices (number caught/100 trap nights), by stand age, 1979-1981

	Stand Age				
	Zero	Seed	Sap.	Pole	Saw.
otton mouse	5.00	0.22	2.34	0.89	1.81
h-ft. mouse	2.27	5.33	0.45	0.28	0.17
olden mouse	0.00	2.22	2.88	1.20	1.11
. ha. mouse	0.45	4.67	0.90	0.14	0.35
h-tl. shrew	0.91	1.56	1.35	1.64	1.57
ll	9.09	14.89	8.02	4.30	5.50
rap-nights	220	450	1110	2140	5150

able 7.-- Suitability indices, derived from 9070 trap-nights, for forest stand age classes 1979-1981

	Stand Age				
pecies	Zero	Seed	Sap.	Pole	Saw.
otton mouse	30.2	1.3	14.2	5.4	10.9
h-ft. mouse	42.1	98.7	8.3	5.2	3.2
olden mouse	0.0	12.8	16.5	9.4	9.0
. ha. mouse	7.8	79.9	15.4	2.4	6.0
h-tl. shrew	7.7	13.2	11.4	10.3	9.4

able 8.-- Suitability indices, derived from 9070 trap-nights, for forest stand type classes, 1979-1981

	Stand Type[1]					
	Z	P	PU	PS	U	S
otton mouse	34.1	5.4	9.0	20.2	25.2	24.2
h-ft. mouse	47.5	21.8	5.2	0.0	0.0	0.0
olden mouse	0.0	9.6	11.5	4.8	9.6	5.7
. ha. mouse	8.8	21.6	6.7	0.0	0.0	0.0
h-tl. shrew	8.7	12.1	9.2	4.8	0.0	8.5

[1] Z = unforested, P = pine, PU = Pine-Upland Hardwoods, U = Upland Hardwoods, S = Streambottom Hardwoods.

Sample sizes required to detect a 20% change in response rate were estimated with the formula $n=s^2t^2/d^2$ (Steel and Torrie 1980:120) where "n" is the required sample size, "s^2" is the variance of the index, and "t" is the appropriate value from a "t table" at the desired alpha level and observed degrees of freedom. Thus, the required future sampling intensity can be estimated. If the variability in future trapping data could not be reduced below that in the present data set, we would need to repeat the sampling effort of this study to detect at an alpha level of .05 a 20% change in the index for three species: cotton mouse, golden mouse and short-tailed shrew (tab. 4). Increased sampling efforts would be needed to detect a 20% change (tab. 4) in density of white-footed mice and fulvous harvest mice. However, the standard error and thus the required sampling effort could be decreased by concentrating trapping effort in the most suitable environments or at the most suitable times (tab. 7 & 8). We cannot practically evaluate density changes of the other snap-trapped species unless variance could be greatly reduced.

Five species were captured often enough for habitat analysis and had different patterns of habitat preference for the variables used (tab. 9). All habitat variables except stem density were associated with differences in small mammal abundances with this analysis.

Table 9.-- Results of Duncan's Multiple Range Test performed on the 10 habitat parameters used in the study. Species grouped horizontally by the same letter are not significantly different

	Species[1]				
	B. b.	*R. f.*	*P. l.*	*P. g.*	*O. n.*
% Canopy Cover F=12.36,p=.0001	A	B	B	A	A
BA[2] Hardwoods F=7.58,p=.0001	A	B	B	A	A
BA Pines F=4.42,p=.0018	A B	A B C	C	B C	A
Ht dom Hardwood F=8.55,p=.0001	B	C	C	A	B
Ht codom Hard. F=2.31,p=.0584	A B	B	B	A	A B
Ht dom Pine F=5.24,p=.0005	A	A B	B	A	A
Ht codom Pine F=1.85,p=.1207	A B	A B	B	A	A
Stem density F=0.41,p=.8039	A	A	A	A	A

[1] B.b. = *Blarina brevicauda*, R.f. = *Reithrodontomys fulvecvens*, P.l.=*Peromyscus leucopus*, P.g. = *Peromyscus gossypinus*, O.n. = *Ochrotomys nuttalli*

[2] BA = Basal Area.

Community structure is more evident from the habitat preferences indicated by the multivariate discriminant analysis than from the raw trapping data. Three discriminant functions (DF) were generated from the variables used and accounted for 67.3% (DF I), 15.5% (DF II), and 12.3% (DF III) of the total variance, respectively. DF I is weighed most heavily by stand age and % canopy cover and the axis represents a gradient from open, disturbed habitat to a closed canopy forest. DF II is most influenced by the height of the dominant hardwood, and DF III by stem density (tab. 10). Further details on the procedures used and an evaluation of the technique can be found in Smith (1983).

The position of the species along these axes represents their habitat preferences (fig. 1).

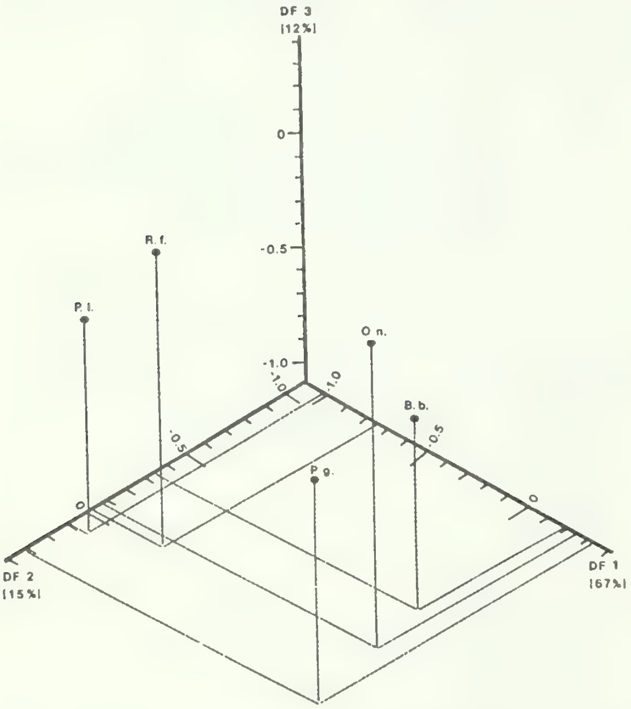

Figure 1.--Positions of the centroids for five small mammal species in 3-dimensional discriminant space. Numbers in parentheses represent the percentage of the total sample variance accounted for by each discriminant function (DF)

All species pairs are separable except *P. leucopus* and *R. fulvescens* (tab. 11).

Even though stem density was the only habitat variable not specifically associated with species differences (tab. 9), it was the most important component to discriminate function III (tab. 10), which was the variable that best separated *Peromysus leucopus* and *Reithrodontomys fulvecvens*.

Table 10.-- Standardized canonical discrimin function coefficients (DF)

Variable	Discriminant Function		
	DF I	DF II	DF
Stand Age	0.46978	-0.35859	0.39
% Canopy Cover	0.45420	-0.59569	0.01
Ht of Dom Hard	0.28698	0.86985	0.07
Stem Density	0.28445	-0.05975	0.86
Ht Codom Hard	-0.15331	-0.58490	-0.53
Ht Codom Pine	0.01985	0.62675	0.13
Basal Area	0.19586	0.31282	-0.30

Scent Posts.--Seven species visited sc posts frequently enough for the data to be a lyzed statistically. The index (mean number visits/100 stations) for the area taken as a wh was approximately 4 times greater for rabbits th for armadillos (*Dasypus novemcinctus*), fox (*Vulpes fulva* and *Urocyon cinereoargentatus* coyotes, or dogs (*Canis familiaris*) (tab. 12 which had indices that were approximately t same.

Table 11.-- F statistics and significance valu between pairs of species. Degrees freedom = 7 and 430)

Species	Species			
	P. g.	*P. l.*	*B. B.*	*O. N*
P. leuco.	9.4676[1] 0.0000[2]			
B. brevi.	3.3808 0.0016	7.7030 0.0000		
O. nutt.	2.7572 0.0082	9.2423 0.0000	2.6166 0.0119	
R. fulv.	6.8926 0.0000	1.5866 0.1374	5.4443 0.0000	5.709 0.000

[1] F value.

[2] P value.

ble 12.-- Scent post indices (visits/100 stations), by species, and sample sizes required (S.S.) to detect a 20% or greater change in scent-post indices, based on the variability exhibited in 1149 scent-post nights, 1979-1981

	Statistics		
ecies	Index	S. E.	S.S.
bbit	15.40	1.06	1609
madillo	4.18	0.59	1827
ccoon	1.48	0.36	1825
ossum	1.22	0.32	1850
g	3.39	0.53	1827
x	3.92	0.57	1828
yote	3.57	0.55	1868
uirrel	0.78	0.26	1911
bcat	0.70	0.24	1814
er	0.09	----	----
g	0.08	----	----
nk	0.09	----	----

For subsequent statistical analysis each ight's results had to be independent. We tested e observed frequency distributions for the 3 ghts with the expected binomial frequencies with tests and found differences for rabbits. foxes d coyotes. Raccoons (*Procyon lotor*) and ossums (*Didelphis virginiana*) had too many cells th expected frequencies less than 1 to be cluded in the analysis. Observations for the mber of nights visited/3-night trapping period s therefore used as the observation for bsequent tests.

Species	χ^2	p
Rabbit	34.34	<0.0005
Armadillo	0.85	>0.6
Dog	3.17	>0.2
Fox	16.53	<0.0005
Coyote	12.02	<0.005

From a runs test for independence of samples Siegel 1956:52-56) at consecutive posts, we found hat armadillos and raccoons (*Procyon lotor*) tened to be recorded at consecutive stations. This as probably due to concentrations of visits at lumps of favorable habitats along the routes ather than visits to consecutive stations by the ame individuals. The stations were 0.2 mi apart, distance probably farther than many of these anmals travel in a night. The habitat was arraned in a series of patches that should have preented random habitat distribution on the lines.

Species	Z	p
Rabbit	1.76	0.08
Armadillo	-2.01	0.04
Raccoon	-2.56	0.01
Opossum	0.43	0.67
Dog	-0.85	0.39
Fox	0.60	0.55
Coyote	-1.52	0.13

Significant seasonal differences of abundance occurred for armadillos, dogs, and foxes (tab. 13).

Table 13-- Scent-post indices (visits/100 stations) and their significance, by season, computed from the raw data set (n-1149), 1980-1981

	Index			
Species	Spring n-293	Summer n-377	Fall n-239	Winter n-240
Rabbit F-2.00,p-.11	18.08	15.12	16.74	11.25
Armadillo F-3.45,p-.02	2.05	5.31	5.86	3.33
Opossum F-2.20,p-.09	2.05	1.86	0.42	0.00
Raccoon F-.099,p-.40	2.05	1.33	2.09	0.42
Dog F-7.01,p-.00	6.48	2.65	0.42	3.75
Fox F-5.35,p-.00	3.75	0.53	5.44	7.92
Coyote F-2.48,p-.06	3.07	2.12	3.77	6.25
Squirrel	1.71	0.00	0.42	1.25
Bobcat	1.37	0.79	0.00	0.42
Total F-2.82,p-.0001	40.61	29.71	35.16	34.59

Scent post indices varied among areas for rabbits, armadillos, raccoons, and foxes (tab. 14). These differences may have been due to different proportions of habitats sampled in the different areas (tab. 1 & 2).

All species were under-sampled at scent posts in our study (*i. e.*, a 20% change in density would not be detected in the future with equal sampling intensity and variance) (tab. 12). However, the sample size required can be reduced by any method that reduces variance (for example, by sampling in 1 season only).

Night-light surveys.--Rabbits were by far the most abundant species detected on the night-light surveys. The index (mean no./100 km) for rabbits is 12 times that of the armadillo, the second most abundant species, (Tab. 15).

Rabbit indices were somewhat lower than many reported in the literature, (Fafarman and Whyte 1979, Wight 1959, and Krug 1960, *e. g.*) especially those from farmland where visibility is greater.

Table 14.-- Area scent-post indices (visits/100 stations) and their significance computed from the raw data set (n=1149), 1980-1981

Species	Index Area 1 n=237	 Area 2 n=341	 Area 3 n=275	 Area 4 n=296
Rabbit F=3.72,p=.00	18.99	18.77	12.36	11.49
Armadillo F=2.64,p=.05	5.06	5.28	4.73	1.69
Opossum F=2.06,p=.10	1.26	1.17	0.00	2.36
Raccoon F=3.23,p=.02	2.11	2.93	0.36	0.34
Dog F=1.25,p=.29	6.33	2.05	2.91	3.04
Fox F=4.47,p=.00	7.59	4.69	1.82	2.03
Coyote F=1.37,p=.25	3.38	4.39	1.82	4.39
Squirrel	1.27	0.88	0.00	1.01
Bobcat	1.27	0.00	1.09	0.67
Total F=2.49,p=.0001	7.26	40.16	25.09	27.02

Significant differences were found in the rabbit (F = 9.93, p =.0001) and opossum (F = 3.33, p = .0383) indices among areas. These differences did not correspond with the results for scent-posts. The inconsistency is almost surely due to differences in proportions of habitat type sampled among areas with the two methods. Representative sampling (*i. e.*, in proportion to habitat availability) was not achieved and was not practical for scent-posts, night-lighting, or track counting in this study because of time constraints. However, meaningful temporal comparisons could be made with these techniques if the same routes were run repeatedly in a similar manner. Locations of the routes are in Ellsworth (1983:173-176,181-182). The variability in habitat proportions can be seen by comparing results from different areas (tab. 12).

Table 15.-- Night-light indices (no./100km) sample sizes (S.S.) of night-li counts needed to produce indic precise enough to detect 20% or great changes in abundance, based on 1 counts (3 areas, 61 occasions), 197 1981

Species	Statistics Index	 S.E.	 S.S
Rabbit	24.47	2.39	14
Armadillo	2.03	0.49	107
Opossum	1.95	0.44	85
Raccoon	0.13	0.09	--
Striped Skunk	0.90	0.31	--
House Cat	0.50	0.22	--
Feral Hog	0.06	0.06	--
Gray Fox	0.12	0.12	--

Table 16.-- Night-light indices, (no./100 km) area, calculated from 61 counts

Species	Index Area 1	 Area 2	 Area
Rabbit[1]	14.83	37.91	20.
Armadillo	1.14	3.16	1.
Raccoon	0.38	0.00	0.
Opossum	1.14	3.51	1.
Striped Skunk	0.00	2.11	0.
House Cat	0.19	0.70	0.
Feral Hog	0.19	0.00	0.
Gray Fox	0.00	0.35	0.

[1] The variable rabbit includes swamp rabbits and eastern cottontails.

Rabbit numbers varied among Areas (F = 9.93 p = 0.0001) as did opossum numbers (F = 3.33, p 0.0383). Sample sizes were too small to make comparisons of the other species.

Significantly different monthly indices fo rabbit were found (F = 2.43, p = 0.0129) (tab 17), with higher values in late winter and spring Rabbit indices were largest before the reproductive season; presumably the rabbits moved to th roadside at this time to consume the new vegetation. In future surveys, more counts should b conducted when the index is large in order t facilitate comparisons. The phase of the moon di not affect the night-light indices significantl (see Ellsworth 1983).

If equal sampling intensity were used in th future, changes of density of 20% could only b obtained with rabbits (tab. 15).

Table 17.-- Night-light indices (no./100 km) for rabbit, by month, 1979-1981[1]

Month	Statistics			
	n[2]	Index	S.E.[3]	C.V.[4]
Jan	9	27.51	10.00	109.01
Feb	36	31.55	6.36	120.89
Mar	36	36.53	7.42	121.87
Apr	18	32.93	5.86	75.50
May	21	13.06	3.67	128.80
Jun	9	16.90	7.28	129.31
Aug	3	6.09	6.09	173.21
Oct	6	7.44	4.71	155.11
Nov	21	16.68	4.92	135.10
Dec	24	14.52	4.89	164.88

[1] Each count was 18.7 km long for a total of 1140.7 km.

[2] Each sample included a count of each of the 3 areas; therefore N = 9 when 3 counts are made in each of the 3 areas. The area is the sampling unit.

[3] S.E. is the standard error of the mean (index).

[4] C.V. is the coefficient of variation of the index.

Sample sizes were low because sampling was done 1 or 2 days after a rain and the weather did not always cooperate. Drought made counting impossible in June and July 1981 (tab. 3). However, this method was the only one that detected many deer and should be continued for that reason. The deer index (mean no. of tracks/km) with equal sampling intensity in the future could detect a 40% change in density. In the future, track sampling should be more intensive.

Species list.--Thirty of the 46 species that are likely to occur in central Louisiana (Lowery 1974) were recorded in this study (tab. 18) and we obtained abundance indices for 26 of these.

Track counts.--Thirteen species were detected by track counting.

Taxon	Index[1]	S.E.
Dog	194.44	54.22
Fox	102.39	63.99
Coyote	23.54	8.16
Deer	93.42	19.45
Armadillo	59.89	10.20
Feral Hog	1.53	1.24
Rabbit	129.15	24.65
Opossum	10.28	6.10
Raccoon	12.20	3.39
Striped Skunk	1.58	0.91
Squirrel	8.28	2.74
House Cat	9.15	5.32
Bobcat	0.28	0.23

[1] Mean no. of tracks/km.

Table 18.-- Species likely to be on the study area and their status as determined by this study

Scientific name[1]	Occurrence			
	Ind[2]	Ob[3]	sign[4]	Ab[5]
Didelphis virginiana	*	y		com
Myotis austroriparius		n		r
Pipistrellus subflavus	*	y		ab
Eptesicus fuscus		n		
Lasiurus seminolus		n		
Lasiurus borealis	*	y		ab
Lasiurus cinereus		n		
Lasiurus intermedius		n		
Nycticeius humeralis	*	y		com
Plecotus rafinesquii		n		
Tadarida braziliensis		n		
Scalopus aquaticus		y		com
Blarina brevicauda	*	y		ab
Cryptotis parva	*	y		r
Dasypus novemcinctus	*	y		ab
Sylvilagus floridanus	*	y		ab
Sylvilagus aquaticus	*	y		ab
Sciurus carolinensis	*	y		ab
Sciurus niger	*	y		ab
Glaucomys volans	*	y		com
Geomys bursarius		n	*	com
Castor canadensis		n	*	r
Oryzomys palustris		n		r
Reithrodontomys humulis		n		r
Reithrodontomys fulvescens	*	y		com
Peromyscus leucopus	*	y		com
Peromyscus gossypinus	*	y		ab
Ochrotomys nuttalli	*	y		ab
Sigmodon hispidus	*	y		r
Neotoma floridana		n		r
Microtus pinetorum		n		r
Rattus rattus		n		r
Rattus norvegicus		n		r
Mus musculus		n		r
Myocastor coypus		n	*	r
Canis latrans	*	y		ab
Urocyon cinereoargentatus	*	y		ab
Vulpes fulva	*	n	*	com
Euarctos americanus		n		r
Procyon lotor	*	y		ab
Mustela vison	*	y		com
Mephitis mephitis	*	y		com
Lutra canadensis		n		r
Lynx rufus	*	y		com
Odocoileus virginianus	*	y		ab
Sus scrofa	*	y		com

[1] Scientific names follow Lowery (1974).

[2] Data on the species was recorded by one of the techniques reported in this document.

[3] A specimen was observed (live or dead) on the study area.

[4] Only sign of the animal (*e. g.* nests, tracks, scats) was observed, not an entire specimen.

[5] Abundance was estimated from indices reported in this document, observations on the study area (specimens or sign), or if we believed none of the techniques were suitable then on the basis of Lowery (1974).

With the possible exception of some bats and human commensals, few species that are likely to be common on the study areas were missed.

Species diversity.--Different methods, sampling intensities, and sampling locations were used for different species throughout this study and species diversity calculations at any particular location could not be compared with values at other locations or in the literature.

SUMMARY AND DISCUSSION

Four of the seven techniques used to index mammals in four study areas of a "loblolly-shortleaf pine, upland hardwood" forest produced satisfactory results. Snap-trapping, scent posts, night-light surveys and track counts for different sets of species. Squirrel leaf-count surveys were efficient but had highly variable results among watersheds and could only be used to compare the same watersheds in time. Results of collecting bats could only be used for determining relative abundance shifts if identical techniques were used in the future. Predator-call surveys were unsuccessful because of the dense cover that was present at many of the sampling stations. Mammal abundance was high with respect to values found in the literature. Of the 46 mammal species believed to occur or to have occurred in central Louisiana, we found 30 and obtained usable indices of 26. Many bats were not found because of sampling problems. We also did not find commensal rodents or species such as the otter (*Lutra canadensis*) that have specialized habitat requirements.

We obtained usable indices of abundance for five small mammal species and trapped three other species. Golden mouse was the most commonly trapped species (158); next were cotton mouse (150), short-tailed shrew (107), fulvous harvest mouse (53) and white-footed mouse (49), respectively.

The short-tailed shrew was ubiquitous in the forest. There were differences in capture frequencies of cotton mice, white-footed mice, and fulvous harvest mice, among both stand types and stand ages. Golden mice captures varied only among stand ages.

Cotton mice were most abundant in "hardwood" stands and "sapling" ages and white-footed mice were most abundant in the "unforested" and "pine" stand types and the "non-stocked" and "seedling" ages. Golden mice were captured most in the early successional stages. Total captures were most frequent in the "seedling" age class.

A more specific habitat analysis with stepwise discriminant functions allowed us to identify habitat requirements in more detail. As expected, the two most closely related species, cotton mouse and white-footed mouse, had the greatest habitat separation. The cotton mouse occupied the more mature forest habitats and the white-footed mouse occupied early successional areas created by logging. The golden mouse occurred in all stages of succession but only where the understory was dense. The fulvous harvest mouse specialized in grassy areas under open canopies. The short-tailed-shrew occurred throughout the area.

The snap-trap sample size would be su cient to determine a 20% change (a rather s change for small mammals) in abundance of three most common species in the future if variance were to remain the same. However, two species with insufficient sample sizes, vous harvest mouse and white-footed mouse, pr habitat types that were relatively rare and th fore sampled less. Differences in these spe could be detected by increasing sample sizes the appropriate habitats. Smaller samples w be adequate in the future if the variance coul reduced. Sampling at times of maximum trap sponse and density (winter in this study) w accomplish this, as well as would analyzing results by habitat type rather than by area.

Snap-traps are poor at sampling some spe such as shrews. We were able to obtain suffic sample sizes because of the wire across the bar, but additional methods could be employ Pit-fall traps would be ideal for shrews and other small mammals, but considerable effort required to set out and maintain a series of th traps.

We obtained information on 12 species mammals with scent-post surveys. Many of th were game and furbearing species of economic portance. We believe sampling intensity shoul increased to 2,000 post-nights in the future increase the precision of the sample. Our sam size, 1,149 post-nights, was sufficient to m some comparisons. The study areas were almost small, 2,000 ac each, for the required sampl intensity. Because we sampled what we thought be all practical locations along logging roads other areas of easy access, we could not incre the number of posts without placing them clo together. That would increase the problem of rial correlation; each post would not be an in pendent sample because mammals could move f post to post. Some evidence of mammals moving tween posts was present in our data but the s results could have resulted from clumping of p ferred habitats. We sampled 4 times/yr and sam sizes could be increased by sampling more f quently.

Different indices were found among areas rabbit, armadillo, raccoon and fox. We belie the differences were due to different proporti of stand ages and types among areas. A knowle of the precise habitat requirements of the spec involved would be required to test this hypot sis.

Seasonal differences were found in scen post response of armadillos, dogs, and foxes. season was preferred by all species.

We surveyed the night-light route 61 tim and observed rabbits, armadillos and opossu enough to analyze the data, but only rabbits we found with enough precision, with this sampli effort, to detect a future 20% change in abundan with sampling of the same precision.

Rabbits varied by area and month and arm dillos varied by area. The differences among a eas was probably due to different habitat distr butions. This technique is a good one for ra bits, especially if the surveys are made at tim of maximum encounter (January through April).

We found 13 identifiable wildlife track ypes on our counts and this method was the only uitable one for deer. It depends greatly on eather conditions and a severe drought limited ur sampling during the study. We only made 45 ounts but we believe approximately 180 are needd. This type of count has promise for testing eer and other mammal abundance, but care must be aken to sample at a known time after a rain or fter clearing the track-bed so that the temporal pan of track accumulation is known. Additionaly, this method can only be used where soils are uitable. Often fill-soil associated with roads akes very good track-beds. We attempted to reate beds in the forest for sampling tracks and ound the soil unsuitable. We could not even deect our own tracks immediately after we made the ed. Edges of water courses were suitable for rack counts in the study areas.

In conclusion, our efforts were adequate to roduce indices of abundance for 26 of the 30 mamal species encountered. Sample sizes were suffiient to identify differences in abundance of some f these species with respect to habitat, area, or eason. However, we were only able to detect a 0% change in abundance in four species when all he data for a method were grouped together. rouping of all the data together would be done if omparisons of the entire study area were to be one because of future treatments on an area asis. Grouping the data together will result in educed variance and increased efficiency only here there are no differences in the abundance ndices among the units lumped. We found diferences in indices in many situations and believe f comparisons are to be made in the future, they hould be made by habitat or season so as to educe the variance and the required sample sizes. omparison among study areas are impractical ecause of different mixes of habitats and mangement among them. Furthermore, temporal comarisons at any place would only be possible where here were no changes in habitat that were nrelated to treatment at that place between the imes of the comparisons.

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Bird Habitat Use and its Measurement on the Catahoula District of Kisatchie National Forest

Robert B. Hamilton and Gary D. Lester

Abstract.--Indices of avian abundance were obtained and compared from transect and point-count data for five stand ages and five stand types on four study areas. From 33 to 134 ac were needed to achieve stable diversity. Diversities varied with season, habitat, and sample size. Transects were more efficient than point-counts.

INTRODUCTION

The "loblolly-shortleaf pine-upland hardwood" forest type is a widespread habitat in the South and occupies about 70 million acres of the Upper Coastal Plain from east Texas and Oklahoma to Florida and Virginia (Byrd and Lewis 1976). It is possible that the flora and fauna of this forest type have undergone change after cattle grazing was initiated with the arrival of the Spanish in the 16th century.

Because of the controversy concerning the effects of cattle grazing on national forests of the South, in 1979 the Southern Forest Experiment Station, USDA Forest Service, began a 10-yr study on the effects of cattle grazing in the "loblolly-shortleaf pine-upland hardwood" and "longleaf pine" forest types. The ultimate objective of the study was to promote sound multiple-use management on southern forest lands. Three phases were identified in the study plan:

1) Gathering pre-grazing baseline data on soils, water, vegetation, and wildlife.

2) Institution of livestock grazing at three intensity levels.

3) Repeating measurements performed in Phase 1.

This study is part of Phase 1; subsequent phases were terminated prematurely because of funding problems.

Methods employed in a base-line study on large tracts with many habitats of various ages should be efficient. Point count and transect methods are both relatively cost-effective (Dawson 1981) and we used both methods in order to evaluate their effectiveness.

Species diversity is an important community parameter that reduces to one number large amounts of relative abundance data (Hair 1980:269). All of the more than a dozen ways that have been used to evaluate species diversity (Peet 1974) depend to some degree on area sampled. However, the sample area required for a valid species diversity measurement is not known.

Specific objectives of this study were t

1) report baseline information on av n abundance on the habitats of the study area;

2) compare point count and line trans t techniques;

3) investigate the minimal sample size quired for calculating valid bird species div sity (BSD) indices for the habitats of the st area; and

4) examine variation in BSD and ot community parameters on the study areas.

We want to thank all those who helped make this study possible. The field work was nanced by the U.S. Forest Service and the Agricultural Center and Louisiana Agricultural periment Station. Most of the work was perfor by Gary Lester and the data on species diversi were used in his M. S. Thesis. The majority the field work was done by Gary Lester with t assistance of Steve Ellsworth and Clint Smi aided by students, Loyd Mitchell, Bill Hickma and Kathy Fouchi. Dr. Robert Noble and Don Re helped with vegetation analysis and set up t vegetation transects that we used. Ahmed Alwi a Mark Dugas of the Department of Experiment Statistics, Louisiana State University, aided the statistical analysis and computer programmin We appreciate the help we received from Fore Service employees, especially Dr. Henry Pears who provided living quarters near the study are and assisted in many other ways.

STUDY AREA

Field work was conducted on four study area in the Catahoula Ranger District of the Kisatchi National Forest. Each of the study areas is ap proximately 2000 ac of predominantly "loblolly shortleaf pine-upland hardwoods". Areas 1-3 ar traversed by maintained gravel roads and Area 4 i bisected by a single paved parish road. The terrain is level to gently rolling with a maximu slope of 10%. Elevations are between 140 ft an 290 ft above sea level. The upland soils are moderately well-drained and consist of loamy topsoil and clayey or loamy subsoils. In the stream bottoms, soils are loamy and poorly drained.

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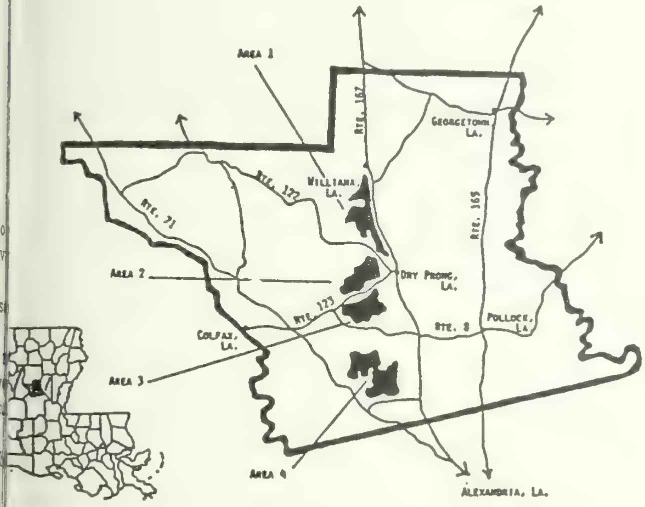
The study areas are in the south-central ortion of Grant Parish, approximately 25 mi north f Alexandria, Louisiana. Area 2 is contiguous ith Area 3 on its north boundary and lies 1.82 mi est of Dry Prong. Area 1 is 0.6 mi northeast of hese areas and Area 4 is about 7.8 mi southwest fig. 1).



igure 1.-- Location of the four study areas in Grant Parish, Louisiana.

Stand-Age Classes

The vegetation had been previously sampled by Reed (1981). He identified five stand ages that were based on age or dbh of dominant trees. Less than 4.5% of the total plots were of the "unstocked" or "seedling" type, and although some of the bird plots occurred in these types, there were not enough to be used for analysis of avian diversity.

As determined by Reed (1981), "sawtimber" was the most frequently occurring age type on each of the study areas (mean = 56.2%), with a low frequency of 40.3% on Area 1 and a high of 76.7% on Area 4. Poles were the next most frequent (mean = 23.2%). In general, the mean age distribution on the study areas is what would be expected with the prevailing management. The stand age distribution was somewhat different among study areas (tab. 1).

Age distribution in the bird plots also varied greatly among study areas, but for the total area bird plot distribution corresponded closely with the total plot distribution. "Sapling" and "sawtimber" were slightly over-sampled and "pole" was slightly under-sampled (tab. 1).

Habitat age distribution of bird study plots in each study area also corresponded closely with the habitat distribution for the total study area. Therefore, any differences found in avian abundance among areas probably could not be attributed to non-representative sampling.

Table 1.-- Relative frequency of occurrence (%) of forest stand ages in each study area and in bird plots, Catahoula Ranger District, Kisatchie National Forest, Dry Prong, Louisiana, 1980

	Area				
Stand Age	1	2	3	4	Total
Unstocked					
Total Area	0.7	0.4	0.0	11.5	2.9
Bird Plots	0.9	0.0	0.0	14.8	3.8
Seedlings					
Total Area	0.7	17.0	0.0	0.0	4.3
Bird Plots	1.8	18.2	0.0	0.0	5.4
Saplings					
Total Area	18.3	8.3	24.5	0.9	13.4
Bird Plots	17.1	12.9	33.1	0.9	16.1
Poles					
Total Area	40.3	29.5	7.2	11.0	23.2
Bird Plots	20.7	27.3	4.1	9.6	15.7
Sawtimber					
Total Area	40.0	44.8	68.3	76.6	56.2
Bird Plots	59.5	41.7	62.8	74.8	59.1

Stand Types

Reed (1981) classified the vegetation into eight stand types. We felt that his distinctions were finer than necessary for our bird sampling and collapsed his types into five. We called his "loblolly-shortleaf, occasional longleaf pine forest"[1] "pure pine" for brevity. Three of his categories: "loblolly-shortleaf pine-upland hardwood", "loblolly-shortleaf-longleaf pine-upland hardwood", and "upland hardwood", were combined into the category "pine-upland hardwood". Our "pine-streambottom hardwood" consists of his "streambottom hardwood" and "loblolly-shortleaf pine-streambottom hardwood-occasional longleaf pine". We used the modified stand type classification when reporting indices of abundance for birds.

The relative proportions of these types varied considerably among the study areas but overall our sample rather closely matched the type distribution as determined by Reed (1981) (tab. 2). "Pine-upland hardwoods" was the predominant stand type (mean = 62.0%) with a frequency varying from 40.3% on Area 2 to 82% on Area 1. "Pure pine" was frequent on Areas 2 and 4 and hardwoods were especially abundant on Areas 1 and 3. The unforested type was especially abundant in Area 4 (tab. 2).

Stand type frequency distributions more closely matched that of the vegetation transects than stand age frequency distributions (tabs 1 & 2) and results for stand type are not likely to be biased by non-representative sampling.

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[1] Descriptions of stand types can be found in Reed (1981)

To make meaningful diversity comparisons among locations of different sizes, diversity at all places of interest must have a constant or nearly constant value that is not affected by the area of the samples, or comparisons must be made among areas of equal size -- the size of the smallest area to be compared. Because using the smallest sample area is undesirable for a variety of reasons, our goal was to find the minimum plot size necessary to attain a stable diversity value. This would facilitate making comparisons among areas and would also provide a diversity value comparable to similarly attained literature values. To maximize our chances of achieving a sufficient sample size for diversity comparisons, we grouped the habitat types even further than described earlier. We included the relatively rare "upland hardwoods" with the "pine-upland hardwoods" and the rare "streambottom hardwoods" with "pine-streambottom hardwoods". This resulted in three rather unique habitat types, each with sample sizes as large as practical.

Ecological Description

The study areas are typical of the "loblolly-shortleaf pine-upland hardwood" forest type. Reed (1981) found that hardwoods constituted 45% of the total basal area. The most prevalent hardwoods were southern red oak (*Quercus falcata*)[2], post oak (*Q. stellata*), blackjack oak (*Q. marilandica*), hickories (*Carya* spp.), sweetgum (*Liquidambar styraciflua*), magnolias (*Magnolia* spp.) blackgum (*Nyssa sylvatica*), flowering dogwood (*Cornus florida*), and red maple (*Acer rubrum*). The major conifers were loblolly pine (*Pinus taeda*), shortleaf pine (*P. echinata*), and longleaf pine (*P. palustris*). Reed (1981) found 180 understory taxa in the study areas, among which yellow jasmine (*Gelsemium sempervirens*), blackberry (*Rubus* spp.), and waxmyrtle (*Myrica cerifera*) were the most frequent. As a whole, the study areas is a patchy collection of internally homogeneous habitats that differ by forest type and stand age. The boundaries between the habitats tend to be relatively sharp. Many large even-aged blocks of 50-200 ac of various ages were present.

Management

The study areas had once been used as open range for cattle and hogs, but there had been no legal grazing on them for the 20 years prior to the study. The forest is presently managed for the production of timber and pulp wood. Clearcutting and prescribed burning are extensively practiced. Regeneration is often done by the seed tree method or by planting.

Table 2.-- Relative frequency of occurrence
of forest stand types in each st
area and in bird plots, Catah
Ranger District, Kisatchie Natic
Forest, Dry Prong, Louisiana, 1980

Stand Type	Area 1	2	3	4	To
Unforested					
Total Area	0.3	0.0	0.0	11.5	2
Bird Plots	0.9	0.0	0.0	14.8	3
Pine-Upl[1] Hards[2]					
Total Area	82.0	40.3	70.5	50.2	62
Bird Plots	79.3	43.9	71.1	54.8	61
Upland Hardwoods					
Total Area	0.3	3.3	1.2	0.4	1
Bird Plots	0.0	3.0	1.7	0.9	1
Str[3] Hardwoods					
Total Area	1.4	0.4	1.7	1.8	1.
Bird Plots	0.9	0.0	0.0	3.5	1.
Pine-Str Hards					
Total Area	6.4	8.3	21.9	3.5	9.
Bird Plots	8.4	9.8	25.6	2.6	11.
Pure Pine					
Total Area	9.5	47.7	4.6	32.6	22.
Bird Plots	10.8	43.2	1.7	23.5	20.

[1] Upl = upland.

[2] Hards = hardwoodas.

[3] Str = streambottoms.

METHODS AND PROCEDURES

Because of the many different combinatio of stand types and stand ages that were presen the relatively small size of some of them, the scattered distribution, and the inaccessibility some of them with respect to passable roads, did not attempt to sample only one habitat at time but used procedures that would let us gath data continuously at a maximum rate in all hab tats. We accomplished this by primarily sampli along transects and by using starting and stoppi points that had convenient access. Although used belt transect lines, we subdivided them a analyzed the results as plots, with the habit characteristic of each plot being that of the associated vegetation sample. We gathered data its times of maximum availability and we gathere as much data as possible at or between the exist ing vegetation sampling points so as to minimiz the amount of vegetation sampling necessary. Fo testing sampling procedures, we alternated sampling schemes along the same transect lines durin each sample count; this protocol not only was efficient, but it minimized variability betwee ethods due to extraneous factors such as weather, ime of day, and time of year.

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[2] Scientific names of plants are from Radford et al. (1968).

ield Methods

A variety of field methods was used in this tudy. The primary sampling of birds was conucted along transects superimposed on vegetation ampling transects that had already been established by Reed (1981) and included sampling points very 200 ft. Reed's lines included 1000 vegetaion sampling points and totaled 38 mi in length. Transects were continuous in each area and generally ran either east-west or north-south, with perpendicular turns near area boundaries. In addition, nocturnal counts were made along existing roads. Each sampling point had been marked with a yellow flag mounted on a 3-ft tall stiff wire and attached to a 3½ ft steel reinforcing rod. Orange plastic flagging was used to help mark the transects.

Transects.--In each area, we selected two segments of the vegetation transects that reflected that area's stand composition (tabs. 1, 2) and used these segments for bird sampling. Additionally, an attempt was made to limit to two the number of stand ages/transect and to make end points easily accessible. In order to meet these criteria, it was necessary to alter the transect routes somewhat by establishing, a total of 10 new points at critical locations. The resulting lines served as mid-points for a continuous series of both bounded and unbounded belt-transects plots. For bounded plots, birds were counted for an estimated 25 m (82 ft) on each side of the transect. This width was selected because it was the smallest distance that allowed a reasonable chance of detecting birds in the densest habitats. The plot border along the transect line of each plot was midway between vegetation sampling points, or 100 ft from the center. Each plot was therefore 200 by 164 ft, or 0.753 ac.

Sampling began at dawn or soon afterwards and lasted approximately 4 hrs. It took approximately 3 minutes to sample each transect plot and we sampled one transect each morning. The number of plots that could be completed before avian activity declined significantly in a morning was estimated to be about 60. Opposite ends of the bird transects were used as points of origin on alternate counts, where possible. Data were gathered during 4 periods: winter 1980 (1 Jan. to 31 Mar.), summer 1980 (1 May to 31 July), winter 1981 (1 Dec. 1980 to 13 Mar. 1981), and summer 1981 (1 May to 2 July). These dates were chosen to reduce the number of migrating birds we encountered.

All birds heard or seen initially within the plots were counted. Birds flying overhead that were merely in transit over the plots were not included.

Circular Plots.--In conjunction with the transect counts, circular point-count plots were sampled for 3 minutes at every fifth plot center. All birds heard or seen using the area within an estimated 25 m (82-ft) radius of the center were tabulated.

Nocturnal owl counts.--We conducted counts at night by driving and stopping every 0.5 mi along the main roads. We started about 30 minutes after sunset, and counted the birds heard or seen in 3 minutes at each stop point.

Statistical Methods

Because of the intermixing of habitats (by "habitat" we mean a discrete block of a particular stand/age class) along the transects and the lack of large blocks of continuous habitats, each habitat type was sampled haphazardly with respect to block size and in no case were the block size patterns consistent among habitats and transects (see Lester 1983, fig. 6-13). Diversity is dependent on block size (Hair 1980), and has only properly been compared among habitats of the same size. Without using a meaninglessly small block size, we could not compare diversities of different block sizes on our transects. If diversity increased with area until reaching a horizontal asymptote, it could be compared among sites as large or larger than necessary to achieve such an asymptote. We attempted to ascertain if the areas sampled were large enough for diversity to reach an asymptote by plotting diversity-area curves.

To calculate a Brillouin index of diversity, we used the formula

$$H = (1/n) \ln N! - \sum \ln n_i!$$

where N is the total number of individuals in the collection and n_i is the number of individuals of the ith species. We used the Brillouin index (H) (Brillouin 1962, Margalef 1958, and Pielou 1975) rather than the Shannon-Weaver H' (Shannon and Weaver 1949) because the Brillouin does not require the assumption of random bird distribution and because it is not biased at non-infinite sample sizes. We used the jackknife method in the diversity calculations. so that statistical comparisons could be made among diversities at different places. Zahl (1977) and Heltshe and Bitz (1979:140-142) discussed the application of the jackknife procedure to the Brillouin index to reduce bias and to estimate sampling variance.

We used the IBM 3033 computer at the Systems Network Computer Center, Louisiana State University, to generate diversity-area curves by randomly selecting plots of a desired habitat type, calculating diversity, and plotting the curves. For the plots, diversity was the dependent variable and number of plots (area) was the independent variable. As each additional plot was added to the sample, we recalculated the diversity of the synthetic community that had accumulated. Diversities were deemed to be comparable when enough plots were available for H values to reach an asymptote, which was defined as a diversity change of less than 0.05/10 plots.

We compared areas (number of plots) necessary to obtain a stable diversity and the diversities themselves with F and t tests, where appropriate. The area required for stable diversity estimates was regarded as a measure of environmental complexity.

F and t tests were used to compare point and transect count methods. An alpha level of 0.05 was used for all tests. Computations were performed using programs of the Statistical Analysis System (SAS) (Helwig and Council 1979).

RESULTS

The number of combinations among four study areas, five stand ages, five stand types, two seasons and the presence of 106 observed bird species precludes the inclusion in this report of tables of the number of birds, by species, that occur with each combination of variables. Potentially 200 tables, each with a number of empty cells, would be required. Data included in this report were obtained for plot types for which relatively large sample sizes existed; at times we obtained these sample sizes by grouping the data in meaningful ways. No data for individual species are included except for one summary tabulation.

The weather was more or less typical for the area (Hamilton et al. 1987:tab. 3), but was not analyzed with respect to bird numbers. There were only 4 days with maximum temperatures over 100½ F in the study period, 3 in July and 1 in August 1980. Because we do not know what the various index values are in "typical years" we are unable to evaluate the influence of weather on the data.

Species Abundance and Richness

The species found in the study are listed below with the number of times (N) each was seen.

Common Name[3]	Scientific Name	N
N. Cardinal	*Cardinalis cardinalis*	771
Blue Jay	*Cyanocitta cristata*	427
Carolina Wren	*Thryothorus ludovicianus*	422
White-eyed Vireo	*Vireo griseus*	389
Tufted Titmouse	*Parus bicolor*	358
Pine Warbler	*Dendroica pinus*	350
Hooded Warbler	*Wilsonia citrina*	335
Car. Chickadee	*Parus carolinensis*	326
Red-eyed Vireo	*Vireo olivaceus*	321
R.-b. Woodpecker	*Melanerpes carolinus*	268
Acadian Flycatch.	*Empidonax virescens*	218
Yl.-breasted Chat	*Icteria virens*	218
American Crow	*Corvus brachyrhynchos*	196
N. Bobwhite	*Colinus virginianus*	128
Kentucky Warbler	*Oporornis formosus*	120
Summer Tanager	*Piranga rubra*	118
B.-and-w. Warbler	*Mniotilta varia*	116
Ruf.-sided Towhee	*Pipilo erythrophthalmus*	111
Wood Thrush	*Hylocichla mustelina*	10
Ru.-cr. Kinglet	*Regulus calendula*	10
B.-g. Gnatcatcher	*Polioptila caerulea*	10
Yel.-rp. Warbler	*Dendroica coronata*	10
Pil. Woodpecker	*Dryocopus pileatus*	9
Yel.-thr. Vireo	*Vireo flavifrons*	8
N. Flicker	*Colaptes auratus*	8
Yel.-bil. Cuckoo	*Coccyzus americanus*	7
E. Wood-Pewee	*Contopus virens*	7
American Robin	*Turdus migratorius*	76
Mourning Dove	*Zenaida macroura*	75
G. Cr. Flycatcher	*Myiarchus crinitus*	72
Brown Thrasher	*Toxostoma rufum*	71
Hermit Thrush	*Catharus guttatus*	63
Br.-hd. Nuthatch	*Sitta pusilla*	62
Rd.-br. Nuthatch	*Sitta canadensis*	60
Worm-eat. Warbler	*Helmitheros vermivorus*	56
Br.-hd. Cowbird	*Molothrus ater*	53
Indigo Bunting	*Passerina cyanea*	49
Yel.-br. Sapsucker	*Sphyrapicus varius*	40
Gd.-cr. Kinglet	*Regulus satrapa*	37
Com. Grackle	*Quiscalus quiscula*	27
Wh.-thr. Sparrow	*Zonotrichia albicollis*	27
Downy Woodpecker	*Picoides pubescens*	24
R.-h. Woodpecker	*Melanerpes erythrocephalus*	22
Fish Crow	*Corvus ossifragus*	20
Cattle Egret	*Bubulcus ibis*	17
Prairie Warbler	*Dendroica discolor*	16
Com. Yellowthroat	*Geothlypis trichas*	13
Brown Creeper	*Certhia americana*	12
Br.-winged Hawk	*Buteo platypterus*	11
N. Mockingbird	*Mimus polyglottos*	10
Turkey Vulture	*Carthartes aura*	10
Eastern Phoebe	*Sayornis phoebe*	9
Dark-eyed Junco	*Junco hyemalis*	8
Gray Catbird	*Dumetella carolinensis*	8
Hairy Woodpecker	*Picoides villosus*	8
Barred Owl	*Strix varia*	7
Cedar Waxwing	*Bombycilla cedrorum*	7
Chipping Sparrow	*Spizella passerina*	7
Fox Sparrow	*Passerella iliaca*	7
Sh.-shinned Hawk	*Accipiter striatus*	7
Am. Woodcock	*Scolopax minor*	6
Black Vulture	*Coragyps atratus*	6
Orchard Oriole	*Icterus spurius*	6
Rd.-sh. Hawk	*Buteo lineatus*	6
Ch.-will's-widow	*Caprimulgus carolinensis*	5
Am. Goldfinch	*Carduelis tristis*	4
Bachman's Sparrow	*Aimophila aestivalis*	4
O.-cr. Warbler	*Vermivora celata*	4
Red-tailed Hawk	*Buteo jamaicensis*	4
R.-th. Hummingbird	*Archilochus colubris*	4
Song Sparrow	*Melospiza melodia*	4
Field Sparrow	*Spizella pusilla*	3
Wh.-cr. Sparrow	*Zonotrichia leucophrys*	3
American Kestrel	*Falco sparverius*	2
Blue Grosbeak	*Guiraca caerulea*	2
Chimney Swift	*Chaetura pelagica*	2
Cooper's Hawk	*Accipiter cooperii*	2
Northern Oriole	*Icterus galbula*	2
Proth. Warbler	*Protonotaria citrea*	2
Purple Finch	*Carpodacus purpureus*	2
Mississippi Kite	*Ictinia mississippiensis*	2
R.-w. Blackbird	*Agelaius phoeniceus*	2
Wh.-fronted Goose	*Anser albifrons*	2
Winter Wren	*Troglodytes troglodytes*	2
Wood Duck	*Aix sponsa*	2
Y.-cr. Night-Heron	*Nycticorax violaceus*	2
Eastern Kingbird	*Tyrannus tyrannus*	1

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[3] Common and Scientific names of birds are from the AOU Check-list (AOU 1983).

Gr.-backed Heron	*Butorides striatus*	1
Lark Sparrow	*Chondestes grammacus*	1
Little Blue Heron	*Egretta caerulea*	1
Loggerhead Shrike	*Lanius ludovicianus*	1
Northern Parula	*Parula americana*	1
Painted Bunting	*Passerina ciris*	1
Scarlet Tanager	*Piranga olivacea*	1
Snow Goose	*Chen caerulescens*	1
Solitary Vireo	*Vireo solitarius*	1
Swainson's Warb.	*Limnothlypis swainsonii*	1
Eastern Bluebird	*Sialia sialis*	1
Great-horned Owl	*Bubo virginianus*	1
E. Screech Owl	*Otus asio*	1
Swamp Sparrow	*Melospiza georgiana*	1
Wild Turkey	*Meleagris gallopavo*	1
House Wren	*Troglodytes aedon*	1
Un. species		69
Un. vireo		46
Un. woodpecker		5
Un. hawk		4

A total of 106 species was identified in the study areas, with Northern Cardinal, Blue Jay, Carolina Wren, White-eyed Vireo and Tufted Titmouse being the most common. Approximately half of the species seen were encountered less than 10 times each.

No endangered species were found. Some migratory species, such as the Hooded Warbler, Kentucky Warbler, and Worm-eating Warbler, that are considered threatened by some people were relatively abundant and the density of Black-and-white Warblers was higher than we have encountered elsewhere in Louisiana. Few game birds were found.

Mean numbers of species and individuals per plot varied among seasons and area (tab. 3).

In each study area, mean density (mean number of individuals/plot) and mean species richness (mean number of species/plot) were higher in the winter of 1981 than the winter of 1980. This relationship was not as pronounced in Area 2 as in Areas 1 and 3 (Area 4 was not sampled the first winter). In the summer, the pattern was reversed with mean density and mean species richness being lower in 1981 than 1980, except for Area 2. In all cases, the comparisons in time were the same for both mean number and mean species richness.

When the data are analyzed by stand type, patterns were discernible although the absolute results for mean density (mean number of individuals/plot) and mean species richness (mean number of species/plot) were quite variable (tab. 4). Much of the variability is probably related to the relatively small sample sizes. The largest mean number of species (8.5) occurred on the "upland hardwood" plots of Area 3 in the summer of 1980. The second largest number (8) was on the same plots in the summer of 1981. The most individuals (17) were on the hardwood plots of Area 2 in the winter of 1981 and second most (11.5) were on the hardwood plots of Area 3 in the summer of 1981. On the other hand, no birds were found on the hardwood plots of Area 4 in the summer of 1981 (tab. 4). There was a tendency for "upland hardwood-pine" plots to have the highest numbers of individuals and species.

Table 3.-- Average number of individuals and species recorded per plot using the line transect and timed area count techniques during 1980 and 1981, by area

AREA	YEAR	SEASON	NUMBERS	SPECIES
1	1980	Winter	3.20588	1.52727
1	1980	Summer	5.70370	4.55455
1	1981	Winter	6.63043	3.01852
1	1981	Summer	3.63918	2.97115
2	1980	Winter	5.11688	1.40769
2	1980	Summer	4.39623	2.95276
2	1981	Winter	5.93333	2.11538
2	1981	Summer	7.30400	5.17692
3	1980	Winter	4.08696	2.11667
3	1980	Summer	7.49167	6.19167
3	1981	Winter	6.18692	3.80000
3	1981	Summer	6.75214	5.73333
4	1980	Summer	6.32456	5.03509
4	1981	Winter	8.30488	1.93913
4	1981	Summer	5.12150	3.63158

With respect to stand age means, results were again quite variable. The highest mean number of species/plot, 12, was found on "seedling" plots of Area 1 in the winter of 1980 as were the most individuals/plot, 15.5. There were no birds found on "pole" plots of Area 4 in the summer of 1981 (tab. 5). No specific pattern emerges from the data, however.

When plots were grouped together by stand type, the most species (48) were on "upland hardwood-pine" in the summer of 1980. Fewest species were (19) in "pole" stands in the summer of 1980 and (17) in the "streambottom hardwood-pine" in the winter of 1980 (tab. 6). The pattern of total number of species increasing in the winter between 1980 and 1981 and decreasing in the summer was again evident and seems unrelated to sample sizes.

When all plots of each stand age were grouped together, the largest number of species (40) was found on "sawtimber" plots in the winter of 1981 (tab. 7). The total number found may be affected by the size of the area sampled (These results can be obtained in tab. 6 and 7 by adding the areas that correspond to the number of plots in the "T" columns for point count and transect methods). In the winter, the total number of species for each age type was higher in 1981 than 1980 but the number present in summer tended to decrease between the 2 years. The differences do not appear related to number of plots sampled; in fact, the largest differences occurred in the "sawtimber" type, the one with the largest sample size (tab. 7).

Species Diversity

Species diversity for both transect and point-count data was calculated for the three stand ages for which we believed there were enough data and for the three stand types in the collapsed habitat type classification (tabs. 6 & 7). We generated diversity by area curves for these habitats, thereby enabling us to evaluate where our sampling intensity was sufficient. Curves for "upland hardwood-pine" are shown for the winter of 1980 (fig. 2) and the summer of 1981 (fig. 3).

The patterns are different for the two seasons and the number of plots required to reach a stable diversity is quite different. The number of plots required for diversity to stabilize for transect counts varied from a low of 44 (33 ac) in "pure pine" in the winter of 1980 to a high of 182 (134 ac) in "sawtimber" in the summer of 1981 (tabs. 6 & 7). A significant difference was found in the number of plots required to attain stability (tab. 6 & 7) in summers between "upland hardwood-pine" stands (145 plots) and "pure pine" stands (67 plots). There was no difference in the winter.

It was necessary to use data from all study areas together to achieve sufficient sample sizes for a habitat to attain H stability. This could not be done if the null hypothesis being tested were that there were "no differences among areas (treatments)". If data from individual habitats could be grouped together because of the lack of statistical differences among them to attain a sufficient sample, it would be desirable to choose study areas as matched as possible in frequency distribution of habitats and in management in order to increase the precision of the sample.

Even with the collapsed habitat classification, we sampled intensively enough to determine valid diversities in only two stand types out of three ("upland hardwood-pine" and "pure pine") and only in one stand age out of three ("saw-timber") in all seasons (tabs. 6 & 7).

There was a significant difference between winter and summer H values in pine stands, and there was no seasonal difference for "upland hardwood-pine" stands.

Among stand age classes, valid H values were determined in both seasons only for "sawtimber" stands in all seasons, but no statistical differences were found between seasons even though the trend is in the expected direction (tab. 6).

Method Comparisons

We did not analyze the unbounded counts because our ability to find various species varied with distance, and our experience in the field led us to doubt the validity of unbounded transects for our sampling situation. Although observers should be alert for endangered species and birds at the higher trophic levels that may occur outside of the transect proper in order to document species composition, we believe that using unbounded transects is unnecessary. We did not observe any species in the unbounded counts that w did not find in the bounded counts.

Table 4.-- Average number of individuals an species recorded per plot using th line transect and timed area coun techniques during 1980 and 1981 (b stand type within each area)

S[1]	T[2]	Area 1 #	Area 1 Sp.	Area 2 #	Area 2 Sp.	Area 3 #	Area 3 Sp.	Area 4 #	Area 4 Sp
1	0	2.00	1.00	----	----	----	----	----	----
1	1	3.44	1.68	3.50	1.46	5.66	2.86	----	----
1	2	----	----	2.00	1.50	----	----	----	----
1	3	8.00	3.00	----	----	----	----	----	----
1	4	2.80	2.16	2.50	0.84	2.33	0.92	----	----
1	5	1.75	0.66	2.40	1.42	2.37	1.70	----	----
1	7	3.20	1.33	7.51	1.48	----	----	----	----
2	0	7.00	7.00	----	----	----	----	9.00	5.7
2	1	5.44	4.22	3.90	2.72	7.27	6.07	5.23	4.5
2	2	----	----	7.00	3.25	11.50	8.50	2.00	2.0
2	3	4.00	4.00	----	----	----	----	6.50	5.0
2	4	6.77	5.88	5.16	3.76	7.80	6.45	6.00	5.33
2	5	6.62	5.37	5.71	4.57	7.47	6.00	5.63	5.09
2	7	5.18	4.27	4.26	2.73	6.00	5.50	7.14	5.62
3	0	1.00	1.00	----	----	----	----	10.10	2.82
3	1	6.13	2.97	6.90	2.33	6.63	3.98	12.00	1.42
3	2	----	----	17.00	2.25	9.00	7.50	4.00	4.00
3	3	2.00	2.00	----	----	----	----	4.00	1.50
3	4	3.87	2.62	4.70	2.30	4.92	3.48	2.50	1.00
3	5	8.90	3.13	2.66	0.85	6.06	3.21	5.00	1.90
3	7	10.00	3.66	5.16	2.01	10.00	4.50	5.16	2.01
4	0	1.00	1.00	----	----	----	----	7.05	4.82
4	1	3.81	3.14	8.83	5.13	6.82	5.80	4.59	3.63
4	2	----	----	1.50	1.50	12.50	8.00	0.00	0.00
4	3	1.00	1.00	----	----	----	----	5.00	3.25
4	4	3.37	3.12	6.00	5.61	6.36	5.78	3.33	2.66
4	5	3.46	2.33	5.00	4.57	6.36	5.78	7.00	3.54
4	7	3.50	3.00	6.98	5.45	8.00	5.00	4.32	3.19

[1] Season: 1 - winter 1980, 2 - summer 1981, 3 - winter 1981, 4 - summer 1983.

[2] Stand Type: 0 - "non-forested", 1 - "loblolly, shortleaf, upland hardwoods", 2 - "upland hardwoods", 3 - "streambottom hardwoods", 4 - "loblolly, shortleaf, streambottom hardwoods, occasional longleaf", 5 - "loblolly, shortleaf, longleaf, upland hardwoods", 7 - "loblolly ,shortleaf, occasional longleaf".

Nocturnal Counts

Screech Owls, the most abundant nocturnal bird, were found an average of 1.22 times/stop. There were obvious seasonal differences that were probably related to seasonal detectability differences as well as to the expected seasonal abundance pattern changes. Barred Owls, which are usually regarded as a bottomland species, were much more abundant than Great Horned Owls (table 8). Chuck-will's-widow was relatively abundant, 0.44/stop, when it was present during its breeding season (tab. 8).

Table 5.-- Average number of individuals and species recorded per plot using the line transect and timed area count techniques during 1980 and 1981 (by stand age within each area)

		Area 1		Area 2		Area 3		Area 4	
S[1]	A[2]	#	Sp.	#	Sp.	#	Sp.	#	Sp.
1	1	2.00	1.00	----	----	----	----	----	----
1	2	5.50	5.50	12.10	2.30	----	----	----	----
1	3	3.09	1.53	12.10	2.30	7.53	4.46	----	----
1	4	2.33	0.85	2.73	1.30	1.00	0.33	----	----
1	5	3.23	1.43	2.48	0.94	2.78	1.40	----	----
2	1	7.00	7.00	----	----	----	----	----	----
2	2	5.50	5.50	3.56	2.40	----	----	----	----
2	3	4.68	3.78	2.42	1.75	7.64	6.25	2.00	2.00
2	4	4.63	3.73	5.25	3.00	7.20	5.60	3.72	2.81
2	5	6.04	4.80	4.75	3.47	7.43	6.19	6.17	5.22
3	1	1.00	1.00	----	----	----	----	10.10	2.82
3	2	10.50	2.50	6.38	2.31	----	----	----	----
3	3	8.05	3.36	9.11	1.64	7.65	4.53	4.00	4.00
3	4	3.00	1.60	5.08	1.94	2.60	2.20	12.20	2.45
3	5	7.05	3.39	5.51	2.29	5.59	3.52	7.44	1.67
4	1	1.00	1.00	----	----	----	----	7.05	4.82
4	2	4.50	4.50	7.76	5.68	----	----	----	----
4	3	3.17	2.72	11.40	4.05	6.76	6.07	----	0.00
4	4	3.68	2.90	5.38	4.72	4.60	4.40	4.66	2.90
4	5	3.77	3.04	7.11	5.61	6.89	5.64	4.76	3.52

[1] Season: 1 - winter 1980, 2 - summer 1981, 3 - winter 1981, 4 - summer 1983.

[2] Stand Ages: 1 - non-stocked, 2 - seedling, 3 - sapling, 4 - poles, 5 - sawtimber.

Valid diversities could not be generated from the point count data. In no case did point-count plots' diversity area curves stabilize, but the maximum number of plots available (53) was near the minimum number required (tabs. 6 & 7).

DISCUSSION AND SUMMARY

We gathered base-line data on bird abundance along a preexisting vegetation transect in four study areas of predominantly "loblolly-shortleaf pine-upland hardwood" forest on the Catahoula District of the Kisatchie National Forest of Louisiana. The bird transects approximated the habitat distribution as determined from a vegetation transect (Reed 1983). Data on bird abundance were gathered both when moving down the 50 m wide transect in plots 200 ft long and when stationary in a circular plot with a radius of 25 m.

The only data for each of the 106 individual species reported are the total number of observations during the four study periods. Individual species data were combined and mean density and mean richness per plot were calculated by area, season, and habitat.

The community data were extremely variable (tabs. 3-5) but because of consistent patterns between years, the variability was a function of fluctuation in avian abundance and not inadequate sampling. Habitat differences among study areas probably accounted for the different pattern among areas. Areas 2 especially and Area 4 to a lesser extent were more variable with respect to habitat (especially stand age) and included more young ages and more "pure pine" (tabs. 1 & 2) than the mean value for the areas as a whole. The differences in mean density and mean species richness between years and the different patterns in summer and winter were probably related to the migratory nature of the avian communities on the study areas and could have been due to events that occurred on a migrant's breeding grounds, on a migrant's wintering grounds, or during migration as well as to what happened to residents and migrants on the study areas themselves. Because variation in abundance of migratory birds may be due to events that have occurred elsewhere, it will be very difficult to link changes in abundance with any particular treatment without careful experimental design.

Table 6.-- Seasonal bird species diversities (BSD) derived from two field techniques and associated with three stand types within the catahoula ranger District, Kisatchie National Forest (R - No. of plots required for BSD to stabilize, T - total no. of plots surveyed, UHP - "upland hardwood-pine", P - "pure pine", PSH - "pine-streambottom hardwood")

			Transect				Pt Count	
S[1]	Type	N[2]	BSD	R	BSD	T	BSD	T
1	UHP	26	2.70[3]	70	2.71	90	2.30	24
2	UHP	48	2.75	132	2.80	180	2.62	48
3	UHP	43	2.62	94	2.67	180	2.25	48
4	UHP	38	2.82	158	2.82	180	2.35	48
1	P	24	2.22	44	2.25	55	2.00	13
2	P	40	2.85	64	2.85	75	2.47	19
3	P	26	2.02	70	2.06	80	1.47	19
4	P	33	2.75	70	2.75	80	2.00	19
1	PSH	17	DNS[4]		0.79	1	1.28	8
2	PSH	35	DNS		1.24	4	0.35	1
3	PSH	28	DNS		0.79	4	2.18	13
4	PSH	26	DNS		0.76	4	0.00	1

[1] Season: 1 - winter 1980, 2 - summer 1981, 3 - winter 1981, 4 - summer 1983.

[2] N - number of species found in the habitat type.

[3] BSD is Brillouin Index, H.

[4] DNS - Did not stabilize.

If the affects of density changes due to events elsewhere were different among the avian communities that inhabited the different habitats of the study area, as appears to be the case, analysis of patterns becomes even more complicated because the habitat mixes on the areas were not identical.

Species richness is a component of species diversity (Tramer 1969) and, like diversity, tends to increase to an asymptote with sample size. The large number of species in "upland hardwood-pine" may have been almost a maximum number because of the large sample size. The smaller numbers for the other habitat types may have been caused by either a sample size being too low for richness values to stabilize or by "upland hardwood-pine" having the capability of supporting more species.

Table 7.-- Seasonal bird diversities (BSD) derived from two field techniques and associated with three stand types within the Catahoula Ranger District, Kisatchie National Forest (R = no. of plots required for BSD to stabilize, T = Total no. of plots surveyed, Sap = "sapling", Pol = "pole", and Saw = "sawtimber")

			Transect				Pt Count	
S[1]	Age	N[2]	BSD	R	BSD	T	BSD	T
1	Sap	22	DNS[3]		2.52	40	2.10	11
2	Sap	38	DNS		2.45	60	1.90	13
3	Sap	33	2.37	50	2.42	60	1.26	13
4	Sap	32	DNS		1.78	60	1.04	13
1	Pol	19	DNS		2.12	37	1.50	9
2	Pol	31	DNS		2.67	55	1.90	10
3	Pol	20	DNS		2.08	55	1.36	10
4	Pol	31	DNS		2.60	55	1.57	10
1	Saw	26	2.37[4]	90	2.37	104	1.92	24
2	Saw	46	2.93	178	2.93	222	2.65	53
3	Saw	40	2.77	160	2.78	222	2.35	53
4	Saw	32	2.82	182	2.82	222	2.57	53

[1] Season: 1 = winter 1980, 2 = summer 1981, 3 = winter 1981, 4 = summer 1983.

[2] N = number of species found in the habitat type.

[3] DNS = Did not stabilize.

[4] BSD is calculated as the Brillouin Index, H.

Densities found were the same for transect and point-count plots. However, we did not gather enough point-count information to be able to adequately determine diversity. A different experimental design would have allowed us to have gathered more point-count data at the expense of transect data and total bird data. Diversities measured in the same habitats by both methods should in theory be the same. However, in all comparisons between methods (tabs. 6 & 7), the method with the most plots (largest area sampled) had the highest diversity. Transect counts usually produced the highest diversity because there were more transect plots, but there were several comparisons where more point-count data were available and diversity was correspondingly higher in the point-count plots. Approximately 76% of c observations were on transect plots and 24% point-count plots.

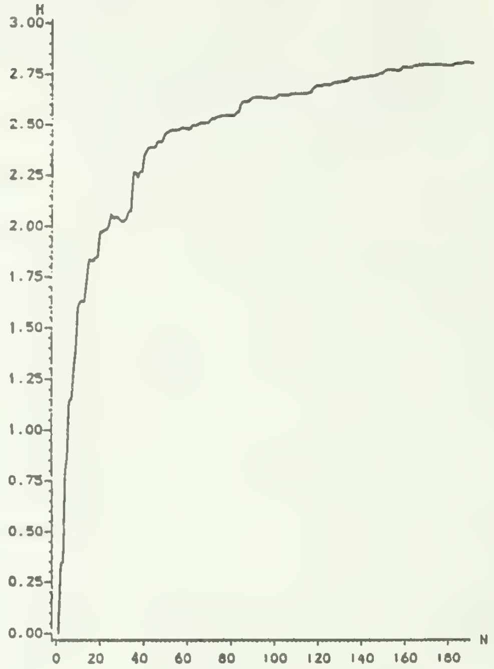

Figure 2.-- Avian diversity (H) plotted agains the number of randomized plots (N used to compute H for "upland harc wood-pine" in the winter of 1980.

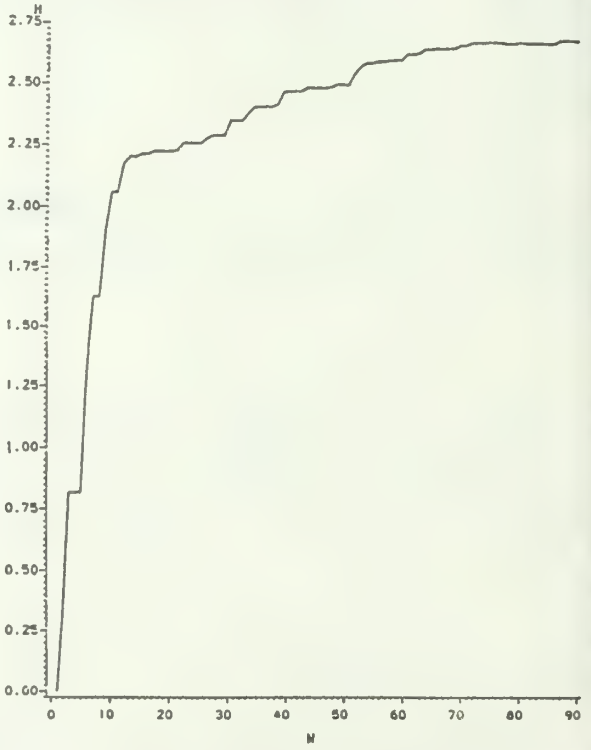

Figure 3.-- Avian diversity (H) plotted agains the number of randomized plots (N used to compute H for "upland hard wood-pine" in the summer of 1981.

counts during the period September 1980 through June 1981 in the Kisatchie National Forest, Catahoula District, Grant Parish, Louisiana

			Species[1]			
eason	Area	Stops	SO	BO	GHO	CWW
all 1980	1	6	14	1	0	0
	2	12	26	4	0	0
	3	6	4	0	0	0
inter 1980-81	1	11	11	7	0	0
	2	7	5	0	0	0
	3	8	7	1	0	0
	4	4	8	1	1	0
pring1981	1	6	8	2	0	0
	4	3	5	0	0	0
ummer 1981	1	6	1	0	0	5
	2	15	14	3	0	7
	3	8	9	4	0	2
	4	3	3	0	0	0
Totals		95	115	23	1	14

[1] SO - Screech Owl, BO - Barred Owl, GHO - Great Horned Owl, CWW - Chuck-Will's-Widow.

We compared densities of birds in the transect plots with densities in the point-count plots and found no difference. Dawson and Bull (1975) concluded that point counts at stations 200 m apart were about as accurate an index of abundance as transect counts. Ratowsky and Ratowsky (1979), however, concluded that the transect method was more efficient. Desante (1981) stated that users of point counts tended to overestimate density when it is low and underestimate density when it is high.

The point count method is sometimes used to compute absolute densities when distances to the observed birds are measured. Although that procedure is theoretically sound, it cannot be used to obtain a true density unless the birds do not move within the study area and one assumes that all birds are found doing each counting period. In addition, it is not necessary to know absolute densities in order to be able to make comparisons.

It is very difficult to gather enough data for valid comparisons under the best of conditions. Any method that does not use all of the time that is available could only be justified if it had a much higher degree of precision. Birds constantly move through the environment and modify their conspicuousness by changing their behavior. There is no reason to expect that consecutive counts of the same area would produce similar results. In fact, we have made a series of 30 consecutive 5-minute counts of an area and did not get the same result twice. Under these conditions, precision cannot be high except under unique circumstances and every effort should be made to ensure that sample size is as large as possible.

It would never be possible to gather as much point-count data as transect data in any given period of time. The point-count method is wasteful of observer time because of the non-observation time spent moving between sampling areas. We concluded that the primary concern of anyone attempting to assess abundance of communities of maximize sample size and therefore we recommend transect plots as the appropriate bird survey method in most situations.

Because diversity increases with sample size (Hair 1980), and because Wilhm (1970) showed that progressively pooled samples reach an asymptote, we devised a computer program to randomly select samples and to create diversity-area curves (Lester 1983). We generated these curves for the habitats mentioned above and could thereby evaluate where diversity comparisons could be made. We developed a procedure for estimating sample sizes required for determining stable species diversities. For this procedure we used random selection of plots by computer to develop synthetic communities and then calculated diversity-area curves for these communities. Objective criteria can be established for determining when adequate sampling has occurred. Diversity comparisons can be made by determining the variance in the synthetic communities with the jackknife procedure.

By establishing that asymptotes had been reached in computer generated synthetic communities randomly drawn from our samples, we found that adequate sampling occurred on transects in all seasons in "pure pine" and "pine-upland hardwood" habitats and in "sawtimber" plots. Insufficient data were available for testing specific habitats (stand-age combinations). "Upland hardwood-pine" needed 82 plots (62 ac) for stability in the winter and 145 (110 ac) in the summer. In situations where there are mixed habitats of various sizes, it would be very difficult to sample individual habitats that are large enough to determine a valid diversity because the required block sizes are not available or, when required block sizes are available, time is wasted moving from one block to another. Data from different types of neighboring habitats can be lumped together, but that is sure to result in noncomparable diversities because of unique habitat requirements of the constituent birds in the avian communities involved. Sampling of synthetic habitats and careful experimental design are necessary to properly test the "null hypothesis" of no difference between experimental units.

Within a given season, the number of plots required to obtain stable diversity is presumably a measure of habitat complexity. Differences in the required number could reflect habitat complexity differences among the types, such as in patterns of vegetational structure. Alternately, differential mixes of stand ages and, therefore, different mixes of vegetational structure among the types (Lester 1983) or a combination of factors could be responsible. Unfortunately, there were not enough plots in specific age-type-season combinations to test for diversity differences in a specific habitat, and the cause of the plot requirement differences cannot be evaluated for a single season. The difference in patterns between winter and summer in single habitats probably reflect more specific habitat requirements for breeding than for wintering and less movement of individuals between different stand ages during the summer. No differences were found in the required number of plots among the stand ages. This is another indication that habitat requirements for birds on the study areas are more specific for stand type than for stand age. If the sample sizes (degrees of freedom) were increased, additional significant differences could have been found.

the winter and the occurrence of large mobile flocks, the equitability component of species diversity (Tramer 1969) is almost surely lower then (Hamilton and Noble 1975:102). It is not surprising that the decrease is more noticeable in "pure pine" stands that were less complex than the "upland-hardwood-pine" stands. This is because many species in the winter feed on seeds that have remained from the previous season and seed abundance is higher in hardwood or mixed stands than pine stands (Hamilton and Noble 1975:102). In fact, there is a statistical difference between H in the winter in "pure pine" stands and "upland hardwood-pine" stands that is due to reduced species richness in winter in the pine stands (tab. 7).

Trends in diversity were much less variable and more in conformance with theory than trends in the other variables studied. Diversity values are related to habitat structure (MacArthur and MacArthur 1961) and are relatively independent of community changes that are unrelated to events on the study areas. Diversity values are thus of use when testing hypotheses that involve change or potential change in vegetational structure.

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Loblolly-Shortleaf Pine Type Discussion

The following questions and responses are the summarized and edited discussion of pertinent ideas pressed during the workshop. While every effort was made to retain the substance and intent of respons, we may have inadvertently altered the intent of the respondent. In many cases, responses to a estion came from several individuals; individuals are identified only by paragraph separation. This produre is followed for all subsequent discussion sections.

estion

What are the effects of forest management on wildlife species relative to tree stand ages or classes?

esponse

Bird communities differ in different stand ages or classes. Seedling stands (1-2 year-old pines) have bundant granivorous bird populations in winter; however, numbers may be high or low in spring depending pon previous site preparation or other management. Sapling stands normally have an abundance of birds uring the breeding season but lower numbers in winter. Insect population levels and degree of tree hinning will influence abundance of bird species in sawtimber stands as well as younger stands.

In Louisiana, amphibians and reptiles were most abundant in sawtimber while mammals were more abunant in grassy regeneration and sapling stands.

In Texas, herps were more abundant in seedling and sapling stands compared to pole stands, but awtimber stands also had relatively abundant herps.

Wildlife diversity is dependent on vegetation stratification. There will be a good diversity of birds f management provides a good diversity of ground, midstory, and overstory canopy layers. Tree stand size s also important; 40-acre clearcuts may be good for deer, but there are some sensitive wildlife species hat require larger openings.

uestion

Would the differences in availability of water on the Texas and Louisiana areas explain herp abundance differences between the two studies?

Response

Herps are linked to the water source in winter but not during spring. However, Texas herp numbers were still higher in spring than in Louisiana. Also, there were some lizards and snakes in seedling and sapling stands that were not found elsewhere. The prairie kingsnake, for instance, prefers a grassy-type understory and was found in a large clearcut area.

Question

Did cattle influence herp, bird, or mammal populations on the study areas?

Response

There were three lizard species found more abundantly in the Louisiana loblolly-shortleaf pine type where there were no cattle; in the longleaf-slash pine type these same lizard species were found more in sawtimber stands, which cattle tended to avoid.

There was a noticeable difference on the Louisiana longleaf-slash pine type between grazed and ungrazed range units. There was more frequent prescribed burning where cattle grazed, which kept ground vegetation down and brush out; this management was probably good for the red cockaded woodpecker and maybe Bachman sparrows, and may have impacted other species positively or negatively.

Question

What are the effects of uneven- and even-age loblolly pine management on mammals and herps?

Response

The amphibian and reptile data for Louisiana indicate that it is best to leave the sawtimber, but this is not so for mammals.

Uneven-age management, with its greater vegetation stratification, will result in higher species diversity. However, some species will be affected positively, others negatively.

Question

Are game animals (rabbits, quail, squirrel, deer) limited by environmental constraints (low soil fertility, low forage yield, poor forage quality) more than by human use or activity? Does grazing actually impact game populations if they are not limited environmentally?

Response

Experinece in Texas indicates environmental factors are generally more limiting. Woodcock, squirrel, doves, quail, etc. are probably not limited by human use or activity. Deer are probably more limited by human use.

From the historical viewpoint, areas managed for grazing tend to have little or no midstory. The midstory was not removed by grazing alone but by a combination of grazing, timber stand improvement, and prescribed burning. Furthermore, there is often heavy hunting pressure that can reduce game populations; consequently, biological management strategies need to be accompanied by sociological considerations.

In Louisiana, deer appear limited by human pressure--primarily poaching. Free-ranging dogs may also be impacting deer and rabbits. If poaching could be reduced, we could better manage game populations.

In multiple-use management, it is impossible to maximize all resources (timber, livestock, wildlife, etc.) at the same time. Within limits, we understand the impact of vegetation stratification on diversity of birds and mammals. Using simple range management practices (manipulation of stocking rates and season of use), we can use livestock to manage vegetation on forest range to benefit some wildlife species. Livestock can be used to attain and maintain certain stratifications, mosaics, or other vegetation variety for wildlife enhancement. In some cases, grazing may have a negative effect, but it can have a positive or at least neutral impact with management. However, several biological and social attributes affect the total and we need to develop models of all factors and optimize the best combination of resource products.

Question

Is the greatest conflict in multiple use management social or biological?

Response

Most groups or individuals tend to be single purpose--either deer, rabbits, cattle, or timber. Generally, we know how to manage the resources but are less knowledgeable in managing the people that use the resources; that is where the biggest problems arise.

Cattle grazing in conjunction with other management practices does change the environment to some degree; whether it is good, bad, or indifferent depends on you, your ideas, and concepts, and how they agree with others in the social framework. Managers have a tough job to evaluate and prescribe management.

Question

Since 100-150 year or older stands were not sampled in the SEP, can these data be used to understand species and community composition changes under longer rotation lengths? Also, was species composition information recorded by stand size classes or other criteria?

Response

Most plants were identified to species and composition by stand size classes were summarized in most original reports. However, for the sake of brevity, we have grouped species into woody, grasses, vines, forbs, and legumes. Greater detail will be available in these proceedings and in the original Forest Service office reports.

In the Texas study, where stands are 50-60 years old, the site is successionally moving towards hardwoods, but from a pine management standpoint, the general tendency is to perpetuate the pine culture through use of fire or mechanical means; this is a value judgement by society. From an environmental standpoint, the bottom line is whether site productivity (soil, watershed, site potential, etc.) is adversely affected. The watershed papers deal with some of the effects of clearcutting, site preparation, and grazing on soil erosion, fertility, etc. It is critical to know the factors that cause a site to degrade and that reduce the management options on that site. Southern forests have been subjected to considerable disturbance, but the land is very resilient or the forests would probably have been totally destroyed long ago. The shortage of old growth stands, especially hardwoods, becomes a societal question. Managers of National Forests are seeing increased interest from environmental groups and the public in general for old age or mature hardwood or pine-hardwood forests.

LONGLEAF-SLASH PINE TYPE

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The longleaf-slash pine-bluestem vegetation type, extending from northwestern Florida and southern Alabama to eastern Texas, and occupying the Western and Central Gulf Coastal Plain, includes about 8 million acres. The longleaf-slash pine-wiregrass type, dominant vegetation type of the pine flatwoods in Florida, southern Georgia, and South Carolina, occupies approximately 20.5 million acres.

Detailed Vegetative Description of the Longleaf-Slash Pine Type,

Vernon District, Kisatchie National Forest, Louisiana

Henry A. Pearson, Harold E. Grelen, Bernie R. Parresol, and Vernon L. Wright

Abstract.--This study was part of the Southern Evaluation Project initiated in 1978 in Louisiana, Mississippi, Florida, and Texas. Plotless sampling was used to inventory tree overstory (stems more than 1 in d.b.h.), circular milacre plots were used for midstory trees and shrubs (stems 1 in or less d.b.h. and more than 5 ft high), and circular 9.6-ft^2 plots were used to measure herbage and browse (up to 5 ft). Soil taxonomic descriptions were verified at each sampling location. Malbis (5,219 acre) and Guyton (1,206 acre) soil series predominated on the area, and longleaf (*Pinus palustris*) and slash (*P. elliottii*) pines were the most abundant trees. Pinehill bluestem (*Schizachyrium scoparium* var *divergens*), swamp sunflower (*Helianthus augustifolius*), and waxmyrtle (*Myrica cerifera*) and blackberry (*Rubus* spp.) were the most abundant grass, forb, and browse, respectively. The overstory trees averaged 62 ft^2/acre basal area, with 49-percent canopy cover and 11 in d.b.h. Snags averaged 0.6/acre, with an average of 1.2 cavities per snag. Herbage yields averaged 744 lb/acre on the four range units, and browse averaged 175 lb/acre. Herbage yields ranged from 120 to over 1,110 lb/acre on the different soils, and browse ranged from 125 to 300 lb/acre.

INTRODUCTION

The Southern Evaluation Project (SEP) was initiated in 1978 at three locations in the longleaf-slash pine (*Pinus palustris* - *P. elliottii*) type (Louisiana, Mississippi, and Florida) and two in the loblolly-shortleaf pine (*P. taeda* - *P. echinata*) hardwood type (Texas and Louisiana). This study was companion to four other inventories of forest vegetation in those four States. The objectives of the study were to (1) describe quantitatively and qualitatively the vegetation of four selected units in the SEP and (2) relate these inventories of vegetation to the major soils of the area. This report provides a detailed description of the longleaf-slash pine type in the SEP in Louisiana. The data were collected in 1979 and 1980 and provide base parameters of vegetation for manipulating, managing, and/or evaluating timber, livestock, and wildlife.

STUDY AREA

The study area (fig. 1) was located approximately 30 mi southeast of Leesville, Louisiana, on the Fullerton Allotment, Vernon Ranger District, Kisatchie National Forest (Yurkunas 1984). The 6,785-acre study area, adjacent to Fort Polk Military Reservation, was comprised of four range units (RU's) having five major soil series (USDA Soil Conservation Service 1979).

The area is characterized by gently rolling topography intersected by numerous drainages. Elevations range from 150 to 350 ft above sea level. Little Sixmile Creek, a tributary of Sixmile Creek, flows through the area. Overstory vegetation consists mainly of longleaf and slash pine, with a bluestem (*Andropogon* spp., *Schizachyrium* spp.) and panicum (*Panicum* spp., *Dichanthelium* spp.) grass understory. Prescribed burning is a common management tool used on the area and is usually accomplished on a 3-year rotation.

Normal annual rainfall is 54 in, with an average annual temperature of 66°F (Hunter 1985). The frost-free season is about 270 days, from late-February through November (Nelson and Zillgitt 1969). July and August are the hottest months

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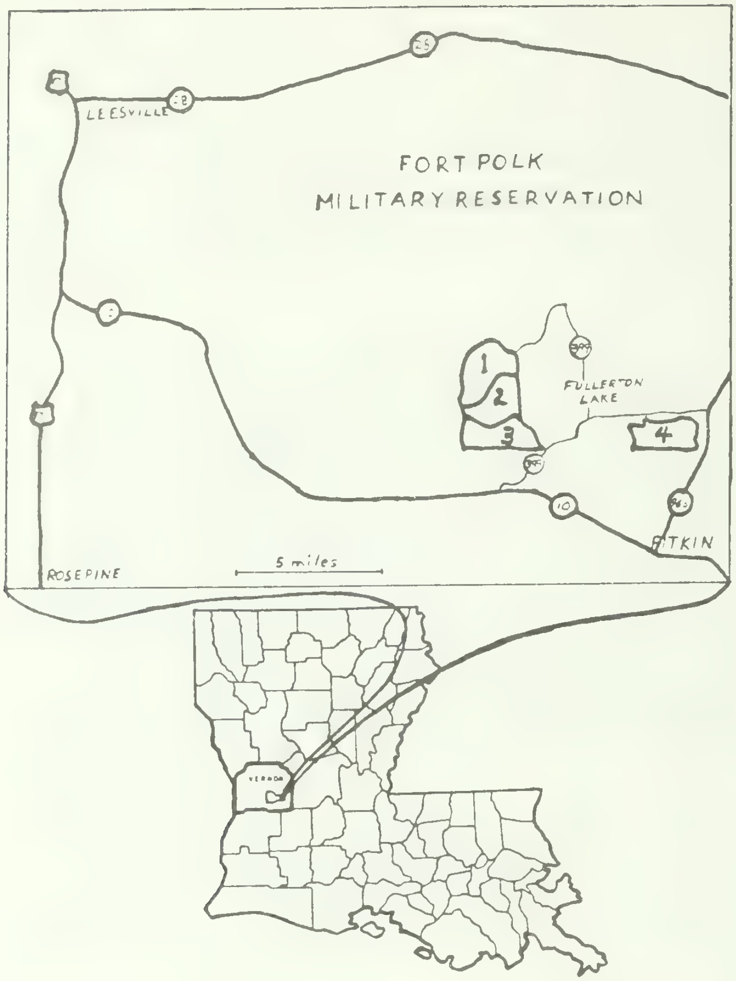

Figure 1.--The study area, Vernon Ranger District, Kisatchie National Forest, Louisiana, showing four range units

(82°F), with December and January being the coldest months (51°F). Annual precipitation during 1979 at McNary weather station was 73 in, with nearly 25 in occurring from May through September; the 1980 precipitation was 55 inches, with 18 in occurring from May through September.

Area soils are mainly the Malbis fine sandy loam series (5,219 acres), a fine-loamy, siliceous, thermic Plinthic Paleudult, and Guyton series (1,206 acres), a fine-silty, siliceous, thermic Typic Glossaqualf (USDA Soil Conservation Service 1979). Other soil series of minor importance include Beauregard very fine sandy loam (186 acres), Susquehanna very fine sandy loam (49 acres), and Cahaba very fine sandy loam (125 acres). None of the samples of vegetation were taken on the Susquehanna soil series.

Grazing history--Cattle had free access to the Fullerton Allotment from 1967 to 1977. In 1977 the allotment was cross-fenced into four RU's (Hunter 1985). Each RU contained 1,300 to 2,300 acres. Control of animal stocking rates and grazing systems was not initiated on the sites until 1981 when watershed studies were installed the three grazed RU's (1, 2, and 3). From 1967 through 1980, cattle stocking rates averaged 37 acres/animal unit (AU). Thereafter, RU's 1 and 3 were grazed continually from March 1 to November and deferred from November 16 to February 28. RU was continuously grazed yearlong. RU 4 was not grazed after 1980. A contiguous RU east of the three grazed units was used during the winter by cattle deferred from RU's 1 and 3; it also served as a reserve pasture for other livestock. Consequently, grazing on the study areas before and during the present inventories reflect the averag stocking rate of 37 acres/AU under yearlong continuous grazing (Hunter 1985).

From 1981 through 1983, livestock were stocked at a yearly average of 47 acres/AU. The yearlong continuously grazed range (RU 2) was stocked at 32 acres/AU, and the seasonally used ranges (RU's 1 and 3) were stocked at 38 and 48 acres/AU, respectively (Hunter 1985). The continuously grazed range (RU 2) was grazed 3.5 month longer than the seasonally grazed units.

Silvicultural history.--Two silvicultural nagement harvest methods (seedtree harvesting and inning) were practiced on the area from 1977 rough 1982 (Hunter 1985). Seedtree harvesting moved most of the pines. Trees left as a seed urce were chosen for phenotype, spacing, and cone oducing characteristics. After harvesting, the acts and stands were site-prepared with a drum opper to remove residual stems and then oadcast-burned.

Thinning harvest was done to enhance producion by reducing competition among pines. One ird of the area was prescribed-burned every year. ines with red-cockaded woodpecker cavities were rotected from harvest and managed as prescribed by SDA Forest Service regional guidelines (USDA orest Service 1985).

METHODS AND PROCEDURES

Scientists from Texas A & M University, ouisiana State University, Mississippi State niversity, University of Florida, and Southern orest Experiment Station participated in developent of common guidelines for sampling and measuring egetation on the SEP. These guidelines were ollowed in making measurements and are described n detail below.

Soil Survey.--An order 2 soil survey was conducted on the Louisiana longleaf-slash pine site y the USDA Soil Conservation Service (SCS), lexandria, Louisiana (Kilpatrick 1987, USDA Soil onservation Service 1979). Soil taxonomic descriptions were verified at each location where vegetation was sampled.

Sampling Design and Intensity.--Permanent sampling points were systematically located 200 ft apart along lines in each of the four RU's (Yurkunas 1984). Initial points on lines were randomly located 100 to 300 ft from the south end of each unit. North-south lines were 1,500 ft apart, with the initial line randomly located 100 to 750 ft from the southwest corner of each unit. No sampling points were located closer than 100 ft of the boundary fences. Permanent sampling points were marked with metal stakes (3/8-in rod) and tree blazing. Compass line and points were located on soil maps.

Sample Frequency and Duration.--Herbage and browse were measured during winter (January and February 1980), spring (April and May 1980), and fall (September through November 1979 and 1980). In spring and winter, only forage botanical composition and use were measured; all forage measurements described in this paper under herbage and browse are fall measurements. Tree, snag, and cavity measurements were taken from February through August 1980.

Point Sampling and Plot Size.--Plotless sampling was used to inventory tree overstory (stems more than 1 in d.b.h.). Midstory trees and shrubs (stems 1 in or less d.b.h. and more than 5 ft high) were measured on circular milacre plots centered on the permanent sampling location (fig. 2). Herbage and browse (up to 5 ft) were measured on a predetermined circular 9.6-ft^2 plot centered 42 in from the permanent sampling location. Both herbage and browse were measured on the selected plots comprising each cluster.

Taxonomic Nomenclature.--Plant names and symbols followed those developed by SCS (USDA Soil Conservation Service 1971, 1982). Other reference manuals included Hitchcock (1950), Radford et al. (1968), Correll and Johnston (1970), or others as needed. Scientific and common names of all plant species or groups identified in the SEP study are listed in the final study report (Pearson et al. 1984).

Overstory Tree Measurements and Classification.--The tree stand at each sampling location was recorded as nonstocked with pine, regeneration (pines 3 years old or younger), saplings (pines more than 3 years old to 4 in d.b.h.), poles (pines 4 to 9 in d.b.h.), or sawtimber (pines more than 9 in d.b.h.).

Pine basal area (square feet per acre) was measured using a 10-basal-area factor prism. Tree diameter at 4.5 ft above ground level (d.b.h.) of prism-recorded trees was measured with a diameter tape. Heights of dominant and co-dominant pines were measured with a clinometer. Tree age was determined from increment borings (cores) of the dominant and co-dominant trees or from National Forest tree planting records. Canopy cover was estimated with a spherical densiometer (Lemmon 1956). Hardwoods were measured for tree basal area, canopy cover, d.b.h., age, and height by the same methods described for pines. Trees per acre (T/A) of hardwoods and pines was determined with the equation

$$T/A = \frac{BAF}{0.005454(d.b.h.)^2} \ ,$$

where BAF is the basal area factor, and d.b.h. is the diameter at breast height in inches. The number of snags occurring within a 1/2-chain radius (0.0785 acre) of the permanent sampling point was defined as any standing dead tree or part of a dead tree at least 10 in d.b.h. and 10 ft tall. All tree species within 1/2-chain of the permanent sampling point were recorded.

Midstory Tree, Shrub, and Vine Measurements.--Trees (stems 1 in or less d.b.h.), shrubs, and vines more than 5 ft high were measured for percentage of canopy cover and height (ft) by species and number of species occurring on the milacre plots. Because only two plots had measurable midstory, these parameters were not included in these results.

Browse.--The current year's growth of trees, shrubs, and vines within 5 ft of the ground (browse) was measured on 9.6-ft^2 plots systematically located near permanent sampling points (fig. 2). Total browse weight (pounds/acre) and foliage ground cover (percent) were estimated on each plot; 20 percent of the plots were clipped (double sampling technique) to determine ovendry weight adjustments (Society for Range Management 1986). Current year's growth of all species was clipped and weighed collectively.

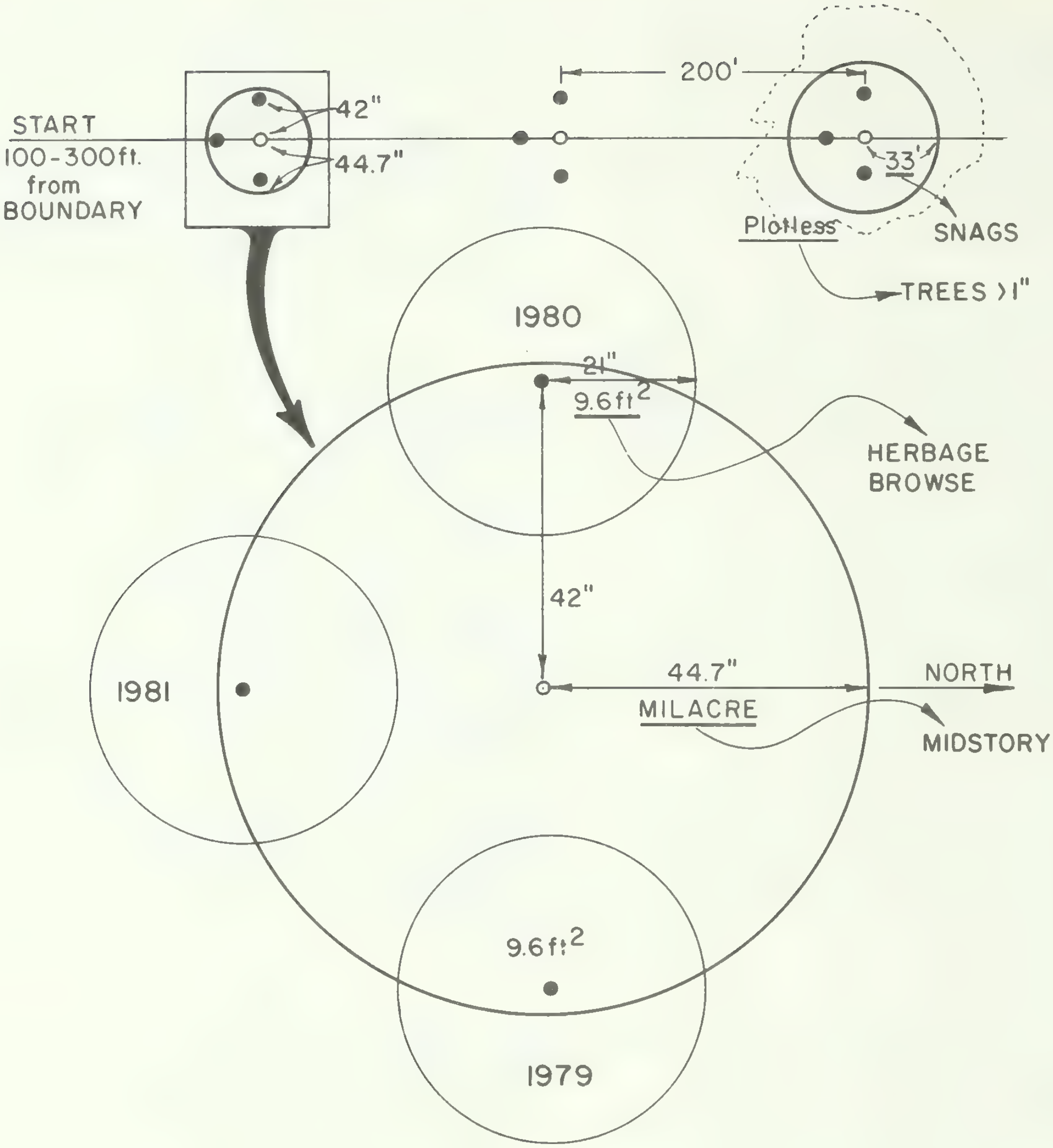

Figure 2.--Plots, clustered around sampling location, for measuring trees, herbage, browse, and snags.

Percentage of botanical composition of browse was estimated for each species making up 10 percent or more of the foliage ground cover. Presence only was recorded for species having less than 10 percent. Species comprising more than 10 percent and those present were used to calculate percentage of botanical composition for species by cover.

Degree of browsing on woody species was recorded in five categories: None; very light--difficult to find browse plants on plot, less than 10 percent of plants or plant portions browsed; light--infrequent evidence of browsing on plot, generally 10 to 35 percent of plants or plant portions browsed; moderate--frequent evidence of browsing, generally 35 to 70 percent of plants or plant portions browsed; and heavy--extensive evidence of plant portions browsed.

Herbage--Herbage (grasses, grasslikes, and forbs) was measured on 9.6-ft^2 plots systematically located near the permanent sampling points (fig. 2); these were the same plots used for browse measurements. Total herbage weight (pounds/acre), foliage ground cover (percent), and basal cover (percent) were estimated on each plot; 20 percent of the plots were clipped (double sampling technique) to determine ovendry weight adjustments. Current year's growth of all species was clipped to a 1-in stubble and weighed collectively.

Percentage of botanical composition of herbage was estimated for each species making up 10 percent of more of the foliage ground cover. Species having less than 10 percent cover were recorded as present. Species comprising more than 10 percent and those present were used to calculate percentage of botanical composition by cover.

Degree of grazing on the herbage species was ecorded in five categories: *None*; *very light*--fficult to find grazed plants on plot, less than 0 percent of plants or plant portions grazed; *ight*--infrequent evidence of grazing on plot, enerally 10 to 35 percent of plants or plant portions grazed; *moderate*--frequent evidence of razing, generally 35 to 70 percent of plants or lant portions grazed; and *heavy*--extensive evience of grazing, generally more than 70 percent of lants or plant portions grazed.

Analysis.--Regression analyses were used to valuate relationships among variables such as oils, trees, herbage, and browse. Both linear nd nonlinear regression models were tested for the est fit. Analyses of variance were used to test ifferences among range units, soils, and other arameters. Statistical significance was accepted t the 0.05 probability level. Forage yields are eported in the text with standard error of the eans. Regression equations are reported showing he reduction in variation due to regression (r^2) with the standard error of estimate ($S_{y \cdot x}$).

RESULTS

Overstory

A total of 650 sample locations were measured for tree overstory, snags, and cavities. Five percent of the study area was open or without measurable trees; the RU's ranged in openness from 2 to 12 percent (RU 1, 12 percent; RU 2, 5 percent; and RU's 3 and 4, 2 percent).

Most of the timber stand acreage was stocked with sawtimber (66 percent), with considerably less acreage in poles (9 percent), seedlings and saplings (14 percent), and regeneration (9 percent); only 1 percent of the acreage was nonstocked according to the 1979 silvicultural stand prescription summaries for the Vernon District. Longleaf and slash pines were the dominant tree species, encompassing 74 to 85 percent of the acreage on the four RU's. Hardwoods occupied 6 to 15 percent of the acreage, with loblolly pine occupying 3 to 14 percent of the area.

Trees.--Longleaf and slash pines were the most common tree species on the study area, including pines or hardwoods, comprising 73 percent of all the trees (76 percent of the trees tallied on RU 1, 80 percent on RU 2, 56 percent on RU 3, and 85 percent on RU 4). RU 3 also had 13-percent occurrence of loblolly pine at the sampling locations, whereas other units had 8 percent or less loblolly pine. Occurrence of shortleaf pine was less than 1 percent on any of the units.

Overstory trees averaged 62 ft^2/acre basal area, with 49 percent canopy cover and 11 in d.b.h. (table 1). There was 0.6 snag/acre, with 1.2 cavities per snag or 0.7 cavity/acre. Pines averaged 26 stems/acre, 50 ft^2/acre basal area, and 34 percent canopy cover, with dominant and co-dominant pines averaging 13 in d.b.h., 45 years of age, and 71 ft tall. Hardwoods averaged 69 stems/acre, 12 ft^2/acre basal area, and 15 percent canopy cover, with dominant and co-dominant hardwoods averaging 10 in d.b.h., 34 years old, and 54 ft tall (Pearson et al. 1984). Average basal area of pines on the four RU's ranged from 43 to 63 ft^2/acre, while hardwoods ranged from 4 to 20 ft^2/acre; canopy cover for pines and hardwoods ranged from 29 to 43 and 9 to 21 percent, respectively. Average d.b.h., age, height, and density of pines on the four RU's ranged from 12 to 14 in, 43 to 47 years, 70 to 73 ft, and 21 to 31 trees/acre; hardwoods ranged from 8 to 11 in, 15 to 73 years, 43 to 60 ft, and 49 to 105 trees/acre, respectively.

Table 1.--Summary of plant characteristics for the four range units within the longleaf-slash pine-bluestem range type, Vernon District, Kisatchie National Forest, Louisiana

Characteristic	Range unit 1	2	3	4	Avg.
OVERSTORY (Pine/Hardwood Trees)					
Canopy cover (%)	49	47	50	52	49
Basal area (ft^2/acre)	61	56	63	67	62
d.b.h. (in/tree)	11	12	13	10	11
Density (No.trees/acre)	125	74	80	136	104
Age (yr) of dominants	33	59	47	29	42
Height (ft) of dominants	61	63	65	57	62
Snags (No./10 acres)	5	4	8	6	6
Cavities (No./10 acres)	8	7	11	2	7
Species (No.)	18	14	20	15	17
UNDERSTORY (Herbage/Browse)					
Herbage yield (lb/acre)	671	724	761	821	744
Woody yield (lb/acre)	169	159	153	219	175
Total yield (lb/acre)	840	883	914	1,040	919
Utilization (%)	21	21	18	14	19

Overstory tree basal area ranged from 54 to 84 ft^2/acre on major soils, and canopy cover ranged from 43 to 75 percent (table 2). Pine basal area, canopy cover, d.b.h., and age were similar on the Beauregard (52 ft^2/acre, 39 percent, 14 in, 40 years) and Malbis (54 ft^2/acre, 36 percent, 13 in, 45 years) soils but were somewhat different on the Cahaba (39 ft^2/acre, 21 percent, 14 in, 32 years) and Guyton (22 ft^2 acre, 10 percent, 16 in, 61 years) soils (table 3).

Basal Area-Canopy Cover Relationships.--Tree basal area and canopy cover regression lines were compared for five overstory types, hardwood, hardwood-pine, slash pine, loblolly pine, and longleaf pine, because foresters manage hardwood and pine stands differently. The data were sufficient only to warrant regression equations above 30-percent canopy cover. Regressions for the basal area-canopy cover relationships of loblolly and longleaf pine were not significantly different and therefore were pooled as one relationship (Pearson et al. 1984). Slash pine regressions were significantly different from the loblolly and longleaf pine regressions. The reduction in variation due to regression was quite low for the hardwoods (13 percent) and the loblolly and longleaf pines (20 percent); therefore, equations are not beneficial for predictive purposes. Only for slash pine was the reduction in variation due to regression (55 percent) somewhat adequate for predicting basal area from canopy cover. The equation for slash pine was

$$BA = 14.493 + 1.721\ CC,$$

where BA is basal area in square feet/acre and CC is canopy cover in percent with a $S_{y \cdot x}$ of 24 ft^2/acre.

Understory

Altogether, 625 sample locations were measured each fall (1979 and 1980) for herbage and browse understory. During spring (1980), 217 locations were measured, but during winter (1980) only 196 locations were measured. Data reported in this paper include only the fall measurements of herbage and browse.

Herbage and Browse Species.--Pinehill bluestem (*Schizachyrium scoparium* var. *divergens*) and low panicum (*Dichanthelium* spp.) species were the most prevalent grasses on the area. Swamp sunflowe (*Helianthus angustifolius*) was the most prevalent forb, and waxmyrtle (*Myrica cerifera*) and blackberr (*Rubus* spp.) were the most common browse. Tephrosia (*Tephrosia* spp.) was the most prevalent legume. Altogether, 279 species or species groups were measured on the plant locations. These included 48 grasses, 1 grasslike group, 8 ferns and mosses, 26 legumes, 56 composites, 74 other forbs, and 66 wood species. More than 320 species or species groups were observed on the area (Pearson et al. 1984).

Herbage and Browse Foliage Ground Cover.--Percentage of ground cover for grasses (48 percent) was highest for pinehill bluestem (20 percent), slender bluestem (*Schizachyrium tenerum*) (5 percent), cutover muhly (*Muhlenbergia expansa*) (5 percent), and low panicums (5 percent) (table 4). Browse foliage ground cover (13 percent) exceeded or equaled 2 percent only for waxmyrtle (3 percent) and blackberry (2 percent). Average percentage of herbage and browse ground cover for the four RU's ranged from 44 to 53 percent for the various forage classes (Pearson et al. 1984). Percentage of ground cover for herbage and browse was highest on Beauregard and Guyton soils (61 percent), lowest or Cahaba (40 percent), and intermediate on Malbis (46 percent).

Table 2.--Summary of plant characteristics for major soils within the longleaf-slash pine-bluestem range type, Vernon District, Kisatchie National Forest, Louisiana

Characteristic	Soil				
	Beauregard	Malbis 1%-3%	Malbis 3%-8%	Cahaba	Guyton
OVERSTORY (Pine/Hardwood Trees)					
Canopy cover (%)	45	43	54	62	75
Basal area (ft^2/acre)	55	54	68	76	84
d.b.h. (in/tree)	14	12	13	13	12
Density (No. trees/acre)	58	78	105	85	86
Age (yr) of dominants	40	36	48	32	67
Height (ft) of dominants	78	57	63	68	72
Snags (No./10 acres)	0	4	4	0	23
Cavities (No./10 acres)	0	4	7	0	31
Species (No.)	5	14	16	13	19
UNDERSTORY (Herbage/Browse)					
Herbage (lb/acre)	1,152	863	661	120	378
Woody (lb/acre)	183	125	213	201	300
Total yield (lb/acre)	1,335	988	874	321	678

Table 3.--Average basal area (ft^2/acre) and d.b.h. (in) for tree species by soil series [1]

	Soil										Weighted average [2]	
	Beauregard		Malbis 1-3%		Malbis 3-8%		Cahaba		Guyton			
Species	BA	d.b.h.	BA	d.b.h.	BA	d.b.h.	BA	d.b.h.	BA	d.b.h.	BA	d.b.h.
Acer rubrum					1.3	3.8	1.1	3.2	5.7	6.5	0.9	5.4
Carya tomentosa					0.1	11.5					0.1	11.5
Cornus florida			0.1	5.3	0.5	3.4	2.2	5.4			0.2	4.2
Fagus grandifolia									0.1	16.3	0.1	16.3
Ilex coriacea									0.8	4.7	0.1	4.7
I. opaca					0.1	8.0			0.2	2.0	T	5.0
Liquidambar styraciflua	2.7	8.7	0.7	8.1	3.6	8.9	3.3	10.2	10.5	8.1	2.5	8.5
Lyonia lucida									0.2	1.8	T	1.8
Magnolia virginiana					0.5	16.4	1.1	17.4	11.7	11.3	1.3	11.9
Nyssa aquatica									0.3	20.0	T	20.0
N. sylvatica			0.3	6.9	0.9	6.6	4.4	13.3	23.5	11.6	2.8	10.9
Persea borbonia					0.1	6.4			0.3	8.3	T	7.7
Pinus echinata			0.1	6.0	0.1	11.1					T	7.7
P. elliottii	27.3	14.9	13.8	10.1	15.5	12.4			7.7	13.6	13.8	11.2
P. palustris	24.0	13.6	34.2	13.4	34.3	14.0	3.3	17.3	9.3	15.9	31.1	13.7
P. taeda	0.7	4.6	2.9	14.4	7.1	12.9	35.6	13.5	4.7	17.7	4.6	13.9
Quercus alba			0.1	7.8			1.1	12.3	0.2	14.8	0.1	10.7
Q. falcata	0.7	13.0	0.7	12.9	2.1	13.4	14.4	14.2	1.0	14.7	1.3	13.5
Q. falcata var. *pagodifolia*									0.2	8.8	T	8.8
Q. incana			T	14.7							T	14.7
Q. marilandica			1.1	10.5	1.5	9.7	1.1	15.0			1.1	10.3
Q. nigra			0.1	11.5			1.1	15.8	6.5	13.4	0.7	13.3
Q. stellata			0.4	7.8	0.9	8.2	3.3	8.1	0.5	9.5	0.6	8.1
Symplocos tinctoria					0.1	3.6	3.3	10.3			0.1	8.6
Toxicodendron vernix									0.2	1.4	T	1.4
Vaccinium stamineum			0.0	2.7							T	2.7
TOTAL	55.3		54.3		68.3		75.6		84.0		61.5	
Weighted average [2]		13.9		12.4		12.7		13.0		11.9		12.5

[1] T = < 0.05 ft^2/acre.

[2] average d.b.h. are weighted by acreage.

Herbage and Browse Weights.--Herbage (grasses and forbs) and browse weights were correlated with foliage ground cover and ocular weight estimates; regression equations and correlation coefficients show the herbage estimates to be slightly more accurate than the browse estimates. Weight estimates corrected with double sampling were used to determine forage yields on the herbage and browse plots. Herbage yields were best determined from herbage weight estimates by the regression equation

$$H = (0.905\ HW)10,$$

where H is herbage yield in pounds/acre and HW is estimated herbage weights in grams/9.6-ft^2 plot. Reduction in variation due to regression was 75 percent with a Sy·x of 29 lb/acre. Herbage yields were also determined from estimates of herbage foliage ground cover, but less accurately than with weight estimates by the equation

$$H = (15.0 + 0.015\ (HC)^2)10,$$

where HC is percentage of herbage foliage ground cover; the variation due to regression was 65 percent with a Sy·x of 34 lb/acre. Herbage yield equations were determined from 247 double-sample plots.

Browse yields (current year's growth) were best determined from woody plant foliage ground cover by the regression equation

$$B = (3.7 + 0.931\ WC)10,$$

where B is browse yield in pounds/acre and WC is percentage of woody plant foliage ground cover. The reduction in variation due to regression was 54 percent with a Sy·x of 16 lb/acre. Browse yield was determined nearly as well from browse weight estimates:

$$B = (7.4 + 0.531\ BW)10,$$

where BW is estimated browse weight in grams/9.6-ft^2 plot. The reduction in variation due to regression was 53 percent with a Sy·x of 17 lb/acre. Browse yield equations were determined from 141 double-sample plots.

Table 4.--Average percent foliage ground cover during fall (1979 and 1980) for forage class, genera, and species[1/]

Genera/Species	Ground cover
GRASSES (total)	47.8
Andropogon spp. (5)	1.7
Aristida spp. (2)	1.9
Axonopus affinis	2.9
Dichanthelium spp.	4.8
Eragrostis spp. (3)	0.7
Gymnopogon spp. (2)	0.5
Muhlenbergia expansa	4.5
Panicum spp. (4)	3.0
Paspalum spp.(7)	1.0
Schizachyrium scoparium var. *divergens*	20.2
S. tenerum	5.0
Other grasses (16)	1.6
GRASSLIKES (total)	1.4
FERNS AND MOSSES (total)	0.5
Pteridium aquilinum var. *pseudocaudatum*	0.4
Other ferns & mosses (7)	0.1
COMPOSITES (total)	3.1
Aster spp. (3)	0.4
Eupatorium spp. (7)	0.5
Gnaphalium spp. (2)	0.1
Helianthus angustifolius	1.0
Heterotheca spp. (3)	0.2
Liatris spp. (5)	0.1
Rudbeckia spp. (2)	0.1
Solidago spp. (4)	0.3
Other composites (27)	0.4
LEGUMES (total)	**1.5**
Desmodium spp. (4)	0.2
Galactia spp. (2)	0.3
Lespedeza spp. (7)	0.1
Stylosanthes biflora	0.3
Tephrosia spp. (2)	0.4
Other legumes (10)	0.2
MISCELLANEOUS FORBS (total)	**2.4**
Acalypha gracilans	0.2
Diodia spp. (2)	1.0
Euphorbia corollata	0.1
Oxalis spp. (2)	0.1
Rhexia spp. (4)	0.1
Ruellia humilis	0.1
Scutellaria spp. (2)	0.1
Tragia spp. (2)	0.2
Other miscellaneous forbs (59)	0.5
BROWSE (total)	**13.1**
Acer rubrum	0.7
Ascyrum spp. (2)	0.2
Gelsemium sempervirens	0.8
Liquidambar styraciflua	0.9
Myrica spp. (2)	3.2
Pinus spp. (4)	0.4
Quercus spp. (7)	0.6
Rubus spp.	2.1
Smilax spp. (6)	0.3
Toxicodendron spp. (3)	0.2
Vaccinium spp. (5)	0.7
Other browse (36)	3.0

[1/] Numbers in parentheses refer to identified species.

Herbage and Browse Yields.--Herbage yields on the area averaged 744 ± 44 lb/acre (table 1). Yields varied among the four RU's, with the lowest in RU 1 (671 ± 47 lb/acre), highest in RU 4 (821 ± 48 lb/acre), and intermediate in RU's 2 (724 ± 41 lb/acre), and 3 (761 ± 40 lb/acre). Yields were not significantly different among the four RU's. Browse yields were 169 ± 19, 159 ± 15, 153 ± 13, and 219 ± 21 lb/acre in RU's 1, 2, 3, and 4, respectively. Browse yields were significantly higher in RU 4 than in the other three units, which were not different from each other.

Overstory tree basal area reduced herbage yields but did not appreciably affect browse yields (table 5). On Malbis soils, for which there were sufficient samples for comparison, herbage yields were significantly less under tree stands of 100 ft^2/acre or more basal area than under tree stands having less basal area (Pearson et al. 1984). Herbage yields averaged 814 lb/acre for the lower tree basal areas (less than 100 ft^2/acre) and 390 the Malbis soils, which differed only in percentage of slope, with higher yields (213 lb/acre) on the 3- to 8-percent slopes than on the 1- to 3-percent slopes (125 lb/acre) (table 2). Analysis of the interactions between overstory basal area and tre type showed that longleaf pine with basal areas o 60 to 99 ft^2/acre had significantly less browse (106 lb/acre) than basal areas greater than 100 ft^2/acre (164 lb/acre). The Beauregard soil seri produced the highest average herbage yields acros all tree densities, with 1,152 lb/acre, while Cahaba yielded the least herbage (120 lb/acre) (table 2). Browse yields were greatest on Guyton soil (300 lb/acre) and least on Malbis soil with 1- to 3-percent slope (125 lb/acre). Guyton soil without trees actually produced the highest herba yields (1,549 lb/acre), and this same soil with a tree basal area of less than 20 ft^2/acre produced the most browse (738 lb/acre). The longleaf pine type had the highest herbage yields (885 lb/acre) under trees, while the hardwood-pine type had the highest browse yields (291 lb/acre).

Comparisons among overstory types (longleaf pine, slash pine, and hardwood-pine) on Malbis so with a 3- to 8-percent slope and basal area of 60 to 99 ft^2/acre showed that herbage yields of the hardwood-pine (354 lb/acre) were significantly le than those of the two pine types (801 lb/acre).

Table 5.--Average fall (1979 and 1980) herbage and browse yields for various ranges of tree basal area

Basal area	Herbage	Browse	Total
ft^2/acre		lb/acre	
0	1,036	129	1,165
1-19	896	176	1,072
20-59	955	169	1,124
60-99	710	165	875
>100	309	207	516

Browse yields were lowest on longleaf pine (143 lb/acre), intermediate on hardwood-pine (184 lb/acre), and highest on slash pine (286 lb/acre), probably due to the burning schedule. The longleaf pine type had been burned more often and more recently, but the younger slash pine had been protected from burning.

Yields on the Malbis soil with a 3- to 8-percent slope and Guyton soil with a basal area of 60 to 99 ft^2/acre in the hardwood-pine type showed no differences for herbage (289 lb/acre) but significant differences for browse; browse yields were 184 lb/acre and 465 lb/acre, respectively. The wetter Guyton soil apparently provided a better site for woody plant growth. Herbage and browse yields were not different between the two hardwood types (hardwood, hardwood-pine) on the Guyton soils under a constant tree basal area of 60 to 99 ft^2/acre. Herbage yields averaged 163 lb/acre and browse averaged 363 lb/acre.

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AMPHIBIANS AND REPTILES OF LONGLEAF-SLASH PINE STANDS IN CENTRAL LOUISIANA

Kenneth L. Williams and Keith Mullin[1]

Abstract.--Amphibians and reptile species composition and abundance were surveyed on four study areas, each 1300-2300 ac, on the Vernon Ranger District, Kisatchie National Forest, in central Louisiana, from August 1979 to May 1981. Four stand size classes (habitats) were sampled within each study area--regeneration, sapling, poletimber, and sawtimber. A variety of census methods were used, including walking transects and fence arrays with pitfalls and funnel traps. Sawtimber stands exhibited the most herpetofauna diversity. Amphibians were not abundant in any stand type. Reptiles were more abundant, but with the exception of three species of lizards, probably not abundant enough to serve as good indicators of habitat change resulting from grazing.

INTRODUCTION

Four study sites were located in the southern part of the Vernon Ranger District, Kisatchie National Forest, Vernon Parish, Louisiana. Three sites are located north of Cravens (Route 10) and one site (no. 4) is north of Pitkin. The overall study area is approximately 6785 acres divided into four fenced sites ranging from 1300 to 2300 acres (Fig. 1). The study sites have been impacted by scheduled burns, military activity, cattle grazing and girtling of hardwoods. Elimination of hardwoods was most noticable in pine dominated creek bottoms.

The overstory is predominately longleaf pine (Pinus palustris) and slash pine (Pinus elliottii) forest. Longleaf pine is a fire resistant species and is considered to be a fire dependant species.

The studies were approached with two main objectives: to determine the kinds of amphibians and reptiles occurring in the four types of habitat, and (2) to obtain quantitative data for each habitat type, which could be utilized in later phases of the study. The overall purpose was to obtain data fulfilling the above two objectives and then utilize this data in later studies to evaluate the effects of cattle grazing on occurrence and abundance.

Due to United States Forest Service timber management practices, the forest is in various stages of development ranging from clearcut areas of varying sizes up through mature pine stands. For sampling purposes, four stand size classes were recognized:

1. Regeneration: "recently site prepared, wit or without young pine seedli
2. Saplings: trees up to 4 inches dbh.
3. Poletimber: trees from 4 inches to 10 inche dbh.
4. Sawtimber: trees 10 inches or more in dbh, most would be classified as imma sawtimber.

Amphibians and reptiles are common animals in this area of Louisiana. Within this area pin woods are probably the least desirable habitat f many amphibians and reptiles (see the list below for species that occur/or may occur in the regio of Louisiana where the study areas are located). numbers following each species are 1=obtained in study, 2=known to occur in immediate similar hab but not obtained in present study, 3=not recorde from general area, but very likely occurs, and 4=range maps show it occurring in this area, but not likely in study area due to lack of suitable habitat.

Species (Amphibia)	Category
Amphiuma tridactylum	4
Siren intermedia	3
Necturus beyeri	4

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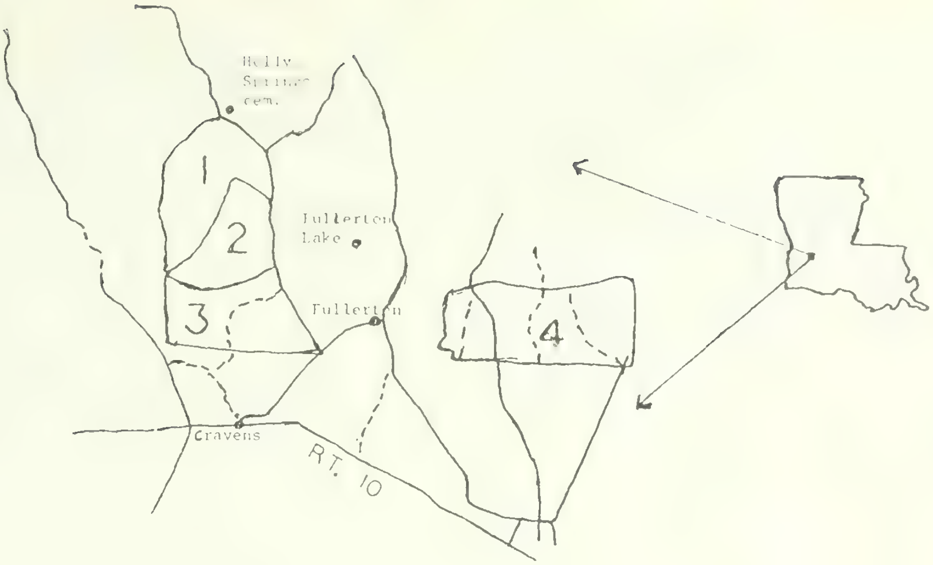

Figure 1. Location of the Vernon Ranger District Study sites, Vernon Parish, Louisiana. (Scale one-half inch=one mile)

Species	Category
Notophthlamus viridescens	4
Ambystoma talpoideum	3
Ambystoma texanum	3
Ambystoma maculatum	3
Ambystoma opacum	3
Desmognathus auriculatum	4
Plethodon glutinosus	4
Eurycea quadridigitata	1
Scaphiopus holbrooki	1
Gastrophryne carolinensis	1
Bufo woodhousei	1
Bufo valliceps	1
Hyla crucifer	1
Hyla cinerea	1
Hyla versicolor	1
Hyla squirella	3
Pseudacris triseriata	1
Acris crepitans	1
Rana clamitans	1
Rana catesbeiana	2
Rana sphenocephala	1
Rana areolata	4

Species (Reptilia)	Category
Alligator mississipiensis	4
Macroclemys temmincki	4
Chelydra serpentina	3
Sternotherus odoratus	3
Sternotherus carinatus	4
Kinosternon subrubrum	3
Graptemys pseudogeographica	4
Graptemys kohni	4
Chrysemys picta	4
Chrysemys concinna	4
Chrysemys floridana	4
Chrysemys scripta	4
Terrapene carolina	1
Trionyx muticus	4
Species	Category
Trionyx spinifer	4
Anolis carolinensis	1
Sceloporus undulatus	1
Scincilla lateralis	1
Eumeces fasciatus	1
Eumeces laticeps	1
Eumeces anthracinus	1
Cnemidophorus sexlineatus	1
Ophiosaurus attenuatus	1
Nerodia erythrogaster	4
Nerodia rhombifera	4
Nerodia cyclopion	4
Regina rigida	4
Regina grahami	3
Thamnophis sirtilis	1
Thamnophis proximus	3
Virginia striatula	3
Storeria occipitomaculata	1
Storeria dekayi	1
Heterodon platyrhinos	2
Diadophis punctatus	3
Opheodrys aestivus	3
Farancia abacura	4
Coluber constrictor	1
Masticophis flagellum	1
Pituophis melanoleucus	3
Elaphe obsoleta	1
Elaphe guttata	1
Cemophora coccinea	1
Lampropeltis triangulum	4
Lampropeltis calligaster	1
Lampropeltis getulus	1
Tantilla gracilis	3
Agkistrodon piscivorus	1
Agkistrodon contortrix	1
Sistrurus miliarius	1
Crotalus horridus	3
Micrurus fulvius	3

Hardwoods allowed to develop along creek bottoms provide more diversity, and kinds and numbers of organisms, including amphibians and reptiles, increase. Many of the species in the above list are absent (code 4) because of a lack of permanent water (except for some man-made ponds). However, as this study indicated, piney woods can sustain a moderate variety of amphibians and reptiles and in a few cases, large populations. The water in the areas, in addition to the ponds, includes only a few intermittant streams. Several species were found only around these meager water sources.

Amphibians and reptiles are basically second or third level consumers in the food chain. They likely are important links in the food web of the piney woods studied.

METHODS AND PROCEDURES

The sampling techniques were as follows:

I. Straight line transects were established and walked. Shrubs and trees (6 ft. or lower) were checked for herpetofauna (especially the lizards *Anolis* and *Sceloporus*), and ground cover was watched, especially for the lizards *Scincella* and *Cnemidophorus*. In addition debris (logs mainly) within 10 yards on either side of the transect were rolled over or if rotten "pulled apart" and searched for amphibians and reptiles.

Each transect was located within a specific habitat type and was searched for a recorded amount of time. A compass was used to maintain a straight line.

II. The other primary method used was a drift fence with associated five gallon buckets (sunk in soil) and funnel traps (Campbell and Christman, 1982, Fig. 2). The traps were randomly established in each of the habitat types and maintained throughout the study.

III. Other census methods were occasionly used with varying success. However, they did allow the addition of several species that would not have been otherwise recorded. These methods were:

1. Accidental observation while moving through the area, often from one trap site to another.
2. Driving the roads at night during warmer months. When a specimen was discovered in this manner, the type of habitat closest was recorded.
3. At the beginning of the study, quadrats were randomly set up and walked for a set amount of time. This procedure was discontinued and the transect method (I above) was substituted. The time involved in establishing randomly located quadrats was prohibitive.

The study sites were visited an average of twice a month. Usually two to two two and one-h days were spent in the area each trip. The exce was during very cold weather the visits were les frequent, especially in January. Most of the vi were made by the authors.

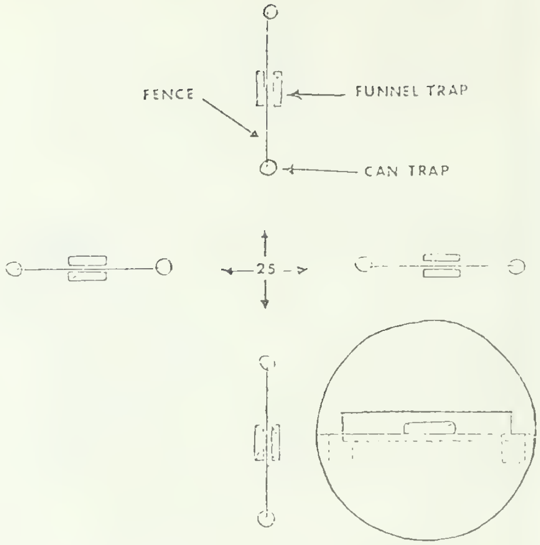

Figure 2. Diagram of drift-fence trap.

Sawtimber was the most abundant habitat; sapling stands were second in abundance. Poleti and regeneration habitats were less available. Consequently sampling efforts, by necessity, wer greater in sawtimber and sapling stands. For al comparisons given here, data are expressed as me unit effort (i.e., number per trap-night or per hour searched).

We used Conant (1975) and occasionly Keiser and Wilson (1979) for species identification. Nomenclature follows Conant (1975) except for watersnakes, where *Nerodia* was used instead of *Natrix*.

RESULTS AND DISCUSSION

Collections revealed surprising diversity o amphibians given the general lack of available water sources (Table 1). Amphibians were most abundant in sawtimber, uncommon in poletimber, and virtually absent in sapling and regeneration Several factors undoubtedly account for this: (1) presence or absence of water, and (2) shaded cover. Both factors were most frequent in sawti Also, certain species were only/or more frequent found along transects, where they crossed creeks One species (*Scaphiopus holbrooki*) was collected on the road during a heavy rain.

Overall, amphibians occurred in such limite numbers and restricted habitats that they would of little value as indicators of habitat change resulting from site disturbance. The narrow-mou toad (*Gastrophryne carolinensis*) might be a poss exception for sawtimber stands.

Reptiles (Table 2) were more numerous and i

Table 1. Number of amphibians trapped or encounted (parenthesis value).

Species	Sawtimber[1]	Pole[1]	Sapling[1]	Regeneration[2]
Eurycea quadridigitata	9(3)	0(2)	0(0)	0(0)
Scaphiopus holbrooki	0(1)	0(0)	0(0)	0(0)
Gastrophryne carolinensis	12(6)	0(0)	0(0)	1(1)
Bufo woodhousei	0(2)	0(0)	0(0)	0(0)
Bufo valliceps	0(1)	0(0)	0(0)	0(0)
Acris crepitans	0(7)	0(2)	0(0)	0(0)
Pseudacris triseriata	0(+)	0(+)	0(0)	0(0)
Hyla cinerea	0(1)	0(0)	0(0)	0(0)
Hyla crucifer	0(2)	0(0)	0(0)	0(0)
Hyla versicolor	0(1)	0(0)	0(0)	0(0)
"frogs"	11(0)	0(0)	0(0)	0(0)
Rana clamitans	1(5)	0(0)	0(0)	0(1)
Rana catesbeiana	0(1)	0(0)	0(0)	0(0)
Rana sphenocephala	3(15)	4(0)	0(0)	0(0)
Totals	36(56)	4(5)	0(0)	1(2)

[1] The data for trapping results represents the totals for 142 trap nights. The data for transect walks represents 70 hours total time.

[2] The data for trapping results represents the totals for 70 trap nights. The data for transect walks represents 35 hours total time.

most cases, less related to water availability and consequently more useful as indicators for later comparative purposes. Lizards were the most abundant reptile group. With the possible exception of box turtles (Terrapene carolina) only certain lizards seem to be abundant (i.e., observable) enough to be useful as indicator species. The three most abundant lizards were the fence lizard (Sceloporus undulatus), the ground skink (Scincella lateralis), and the American anole (Anolis carolinensis). Although Anolis carolinensis and Sceloporus undulatus are found in all habitat types, many records in sapling and regeneration (especially Anolis) were obtained as the transect passed near an isolated hardwood (often black-jack oak).

Table 2. Number of reptiles trapped or encounted (parenthesis value).

Species	Sawtimber[1]	Poles[1]	Sapling[1]	Regeneration[2]
Terrapene carolina	4(6)	2(1)	3(7)	5(0)
Sceloporus undulatus	67(15)	3(4)	1(0)	2(0)
Anolis carolinensis	25(9)	3(2)	1(0)	3(0)
Scincella lateralis	68(20)	4(7)	3(1)	2(0)
Eumeces fasciata	0(1)	0(0)	0(0)	0(0)
Eumeces laticeps	0(2)	0(0)	0(0)	0(0)
Eumeces anthracinus	3(0)	0(0)	2(0)	0(0)
Ophiosaurus attenuatus	0(0)	1(0)	0(0)	0(0)
Coluber constrictor	3(3)	0(1)	1(2)	4(0)
Masticophis flagellum	0(2)	0(0)	0(0)	0(1)
Elaphe obsoleta	1(0)	0(0)	3(1)	0(0)
Elaphe guttata	0(2)	0(0)	0(0)	0(0)
Lampropeltis getulus	0(3)	0(0)	0(1)	0(0)
Lampropeltis calligaster	1(0)	0(1)	0(0)	0(0)
Cemophora coccinea	1(0)	0(0)	0(0)	0(0)
Storeria dekayi	1(0)	0(0)	1(0)	0(0)
Storeria occipitomaculata	1(0)	0(0)	0(0)	0(0)
Thamnophis sirtilis	1(1)	0(0)	0(0)	0(0)
Agkistrodon contortrix	1(6)	1(2)	0(1)	0(0)
Agkistrodon piscivorus	1(22)	0(3)	2(0)	0(0)
Sistrurus miliarius	2(0)	1(1)	0(1)	0(0)
Totals	180(88)	15(22)	17(14)	16(1)

[1] The data for trapping results represents the totals for 142 trap nights. The data for transect walks represents 70 hours total time.

[2] The data for trapping results represents the totals for 70 trap nights. The data for transect walks represents 35 hours total time.

Distribution of the three most common lizards was compared by stand size classes and forest types (Table 3). The loblolly-shortleaf pine site had two areas, with a more uniform occurence among stand size classes. We attribute these differences to more hardwoods and ground cover at Catahoula and the presence of cattle at Vernon. Regeneration was not extensive enough in either area to be sampled adequately.

Table 3. Occurences (%) of the three most common lizards by stand size classes for loblolly-shortleaf (Catahoula) and longleaf-slash pine (Vernon) sampling areas (Catahoula data from Williams and Mullin, 1987).

Species	SAWTIMBER	POLE	SAPLING	REGEN.
Anolis				
Vernon	79	10	3	8
Catahoula	33	29	33	5
Scincella				
Vernon	84	10	4	2
Catahoula	68	28	3	1
Sceloporus				
Vernon	89	8	1	2
Catahoula	62	19	17	2

Scincella lateralis may be the best candidate of the three lizards for monitoring grazing effects. It was the most abundant, lives primarily on the ground under pine or leaf litter, limbs and log debris, and would be subject to the trampling of cattle. Brooks (1967), Johnson (1953), and Turner (1961) give considerable information on the ground skink both on its habitat and density.

As with amphibians reptiles were more abundant in sawtimber where there was more shade and vegetation structural diversity; however, the difference between stand size classes were not as apparent as with amphibians. Snakes were not observable enough by trapping or transect observations to be useful as indicators unless perhaps, all species were lumped.

Interestingly, two of the most commonly encountered snake species copperheads and cottonmouths were poisonous. Many of the cottonmouth (Agkistrodon piscivorus) records were obtained in late summer along drying creeks, but several were taken in traps a considerable distance from water. Copperheads (Agkistrodon contortrix) were active primarily at night and most records were obtained while driving roads. The most abundant harmless snake was the buttermilk snake or racer (Coluber constrictor). It was one of the few species in fair abundance in all four stand size classes. The box turtle (*Terrapene carolina*) was also found in all four areas.

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MAMMALS OF LONGLEAF-SLASH PINE STANDS IN CENTRAL LOUISIANA

KEITH MULLIN AND KENNETH L. WILLIAMS[1]

Abstract.--Four study areas of between 1300 to 2300 acres each, in Vernon Ranger District, Kisatchie National Forest, in central Louisiana, were sampled for mammals from June 1980 through December 1981. Four stand types were sampled within the study areas--regeneration, sapling, poletimber and sawtimber. A variety of sampling techniques were utilized including trapping, drift fence-pitfalls, and scent posts. Sawtimber exhibited the most diversity, sapling was next, followed by poletimber. The two primary sampling methods, Sherman or snap traps, and drift fence-pitfall traps provided information on different portions of the small mammal fauna. Species richness, diversity (Sherman-Weiner), and evenness were calculated separately for trapline and drift fence-pitfall data for each stand class. Similarity of species was calculated for each stand-age class combination. Abundance indices based on all captures were calculated as catch per unit effort for each stand-age class.

INTRODUCTION

Cattle grazing is one aspect of the U.S. Forest Service's multiple-use forest management plan for National Forests in the southern United States. The effects of grazing on the diversity and abundance of mammals is not clearly understood. Mammals are an important part of the ecosystem. They fill a wide variety of niches in the southern forest; herbivore, insectivore, carnivore, and omnivore. Any major effects on the forest ecosystem should be reflected in mammalian diversity and abundance at some level. This would be particularly true for small mammals because of their limited locomotor abilities in response to a change in their habitat.

The Forest Service's management plans usually include a harvest of timber and reforestation on selected rotations. There is a continum of tree stand ages because of this, which could have a confounding effect on mammal populations.

The objective of this study was to provide pretreatment data (i.e., no grazing) on mammalian diversity and abundance in four representative age class stands of longleaf pine (Pinus palustris) and/or slash pine (Pinus elliottii) in Louisiana.

The study took place on four study sites in the Vernon Ranger District, Kisatchie National Forest, central Louisiana. Each treatment stand was classified as one of the following stand-age classes: 1) sawtimber, more than 10 inches dbh, 2) poletimber (poles), 4 to 10 inches dbh, 3) sapling, less than 4 inches dbh, and 4) regeneration, no pine or seedlings. Descriptions, locations and sizes of each treatment stand can be found in Williams and Mullin (1987).

Some treatment stands were subjected to scheduled control burns. Military activity (trucks, tanks etc.) from nearby Fort Polk Army base occurred on most of the treatment stands throughout the study. Cattle grazing also occurred on the treatment stands during the study because fences were frequently cut or gates were left open.

A variety of animal species are found in the area where the study was conducted. We extracted a list of mammals from Lowery (1974) which according to his range maps occur in this area. The list is given below with the following category designations: 1=obtained or seen in our study, 2=known to occur in immediate area, but not obtained in our study areas, 3=likely occurs, but not obtained in study area or adjacent areas, and 4=range maps show it as occurring in this area, but not likely

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due to lack of suitable habitat.

Species	Category
Didelphis virginiana	1
Blarina brevicauda	1
Cryptotis parva	1
Scalopus aquaticus	3
Myotis austroriparius	3
Nycticeius humeralis	1
Lasiurus intermedius?	3
Lasiurus seminolus	3
Lasiurus borealis	1
Eptesicus fuscus	3
Pipistrellus subflavus	1
Plecotus rafinesquii	1
Tadarida braziliensis	2
Dasypus novemcinctus	1
Sylvilagus floridanus	1
Sylvilagus aquaticus	1
Sciurus carolinensis	1
Sciurus niger	1
Glaucomys volans	1
Geomys bursarius	1
Perognathus hispidus	1
Oryzomys palustris	4
Reithrodontomys humilis	3
Reithrodontomys fulvescens	1
Peromyscus gossypinus	1
Peromyscus leucopus	1
Ochrotomys nuttalli	1
Sigmodon hispidus	1
Neotoma floridana	3
Microtus pinetorum	1
Ondatra zibethicus	4
Rattus rattus	4
Rattus norvegicus	4
Mus musculus	3
Myocastor coypus	4
Canus latrans	1
Canus rufus (probably hybrids)	1
Vulpes fulva	1
Urocyon cinereoargenteus	1
Procyon lotor	1
Mustela frenata	3
Mustela vison	1
Mephitis mephitis	1
Lutra canadensis	4
Lynx rufus	2
Odocoileus virginianus	1

METHODS AND PROCEDURES

The study took place from 1 June 1980 to 31 December 1981. The study area was visited during two to two and one-half day periods twice each month. The following methods were used to determine the presence of mammal species in the entire study area or on a selected stand-age class and to quantify relative abundance for selected species.

The following sampling techniques were utilized during this study:

1) Trapping. Trap lines were laid out in each of the stand-age classes for two to four nights each month from September 1980 to April 1981. Trapping was abandoned after April due to lack of results in warm weather. Fire ants probably contributed greatly to this. Trapping effort in each stand-age class was approximately proportional to availability. A trap line consi of stations placed 15 yards apart in a straight line. A station was a Sherman live trap and a Museum Special snap trap baited with a mixture o rolled oats and peanut butter. Traps were set just prior to sunset and checked at first light the following day. All animals were identified, standard measurements taken, and removed from th study area. Trap lines were placed in a new are each time. Total trapping effort was 4085 trap nights. Large live traps were set in a non-systematic manner in a limited way. These traps were baited with apples, dog food, or sardines. Animals obtained (racoons and opossums) were identified and released.
2) Drift fence-pitfall traps. Traps built for a related reptile and amphibian study (see Will and Mullin, 1987 for details) were found to b effective for small mammals. Because of this success, additional drift fence-pitfall traps were built. The number of traps in each stan age class was proportional to availability. Fifteen traps were operational for varying amounts of time from May 1980 to August 1981 for a total of 269 trap months. Traps were checked twice each trip (usually 4 times a month)and all captured animals were identifie and removed.
3) Scent posts. Scent posts were established with a cleared area of soil one yard in radiu These were kept clear and the post was usuall scented with canid scent. Scent posts were examined each morning for tracks. It was usually impossible to distinguish between spe of foxes, rabbits and squirrels, thus we simp clumped them into a general category (i.e., foxes, rabbits, and squirrels).
4) Bat shooting and netting. Mist nets were stretched across ponds and logging roads. A variety of net sizes and heights were tryed i the stand-age classes. Bats were also shot near twilight in similar areas. In addition we searched for resting bats under all bridge in the study areas.

5) General observations. Any mammal seen in the study areas during our general movements, found dead or otherwise identified were recorded.

Names and identification of mammals were based on Lowery (1974). Track identification was based on Murie (1974).

Species richness, diversity (Shannon-Wiener and evenness (Krebs, 1972) were calculated separately for trapline data and drift fence-pitfall results for each stand-age class. Similarity of species (Odum, 1971) was calculat for each stand-age combination. Abundance indi based on all captures were calculated as catch per unit effort for each stand-age class.

RESULTS AND DISCUSSION

The two primary sampling methods, Sherman or snap traps (SST) and drift fence-pitfall tra (DFPT), sampled different portions of the small mammal fauna. Specimens from SST were 68% *Peromyscus* spp. while 63% of the DFPT specimens were shrews. Since we do not know how results from the two methods relate to each other it was necessary to present results from both methods.

Overall eight species were sampled using both methods (Table 1). SST captured all eight. DFPT did not capture *Ochrotomys nuttalli* or *Peromyscus gossypinus*. Sawtimber was the stand-age class richess is species, all eight were captured. Regeneration was the poorest in species (Table 1). Even though there was no significant difference species richness among stand-age classes ($X^2=.77$, $P>.05$) differences would probably be expected (Table 2). The regeneration areas were relatively homogenous in habitat structure when compared to the other areas and this should have limited the number of species. Based on Lowery's (1974) habitat descriptions species such as *Reithrodontomys fulvescens*, *O. nutalli*, and *P. gossypinus* should not have been captured in the regeneration and indeed they were not.

Table 1. The total number of species captured in, A-Sherman or snap traps, B-drift fence traps, and C- combined in the four stand-age classes.

	Sawtimber	Poles	Saplings	Regeneration
A	6	4	5	5
B	8	4	5	0
C	8	6	7	5

Lowery's (1974) distribution map for *Microtus pinetorum* showed that it was outside of the range of the study area. *M. pinetorum* was thought to be relatively uncommon where it did occur in the state. The vole, however, was captured in each stand-age class during the study and it made up 20% of the captures from DFPT. This range extension is documented in detail by Williams, et al. (1980).

Both trapping methods showed sawtimber to be the most diverse and even with poles second in both categories (Table 3).

The distribution of overall captures from DFT was significantly different across the four stand-age classes ($X^2=12.29$, $P<.05$). More specimens than expected were captured in the two younger stands, sapling and regeneration. The results from SST were also significant ($X^2=11.17$, $P<.05$). However more than expected were captured in the older stand-age classes. These results are also reflected in the relative abundance indices (Table 4).

Table 2. Percent similarity of species between stand-age classes.

	Sawtimber	Poles	Sapling
Poles	86		
Sapling	93	92	
Regeneration	77	91	83

Table 3. The Shannon-Wiener species diversity index (H), and evenness (e), (range 0-1) for the two trapping methods.

	Sawtimber	Poles	Saplings	Regeneration
	Drift fence traps			
H	1.13	0.63	0.96	0.91
e	.71	.57	.70	.66
	Sherman or snap traps			
H	1.65	1.05	1.32	0.0
e	.85	.76	.82	.0

Shrews were ubiquitous, high numbers were captured in each stand-age class. *Peromyscus gossypinus* and *Ochrotomys nuttalli* while placed in the sawtimber class were usually captured near hardwood areas. The other species captured were relatively uniform in both presence and abundance across the stand-age classes.

Table 4. Number of specimens of each species captured in each stand-age type class. The first number in each column is from the drift fence traps and the second from Sherman or snap traps.

Species	Sawtimber	Poles	Sapling	Regeneration
Cryptotis parva or *Blarina brevicauda*	30-4	18-2	28-4	14-0
Microtus pinetorum	16-3	4-0	6-0	3-0
Reithrodontomys fulvescens	9-4	1-2	9-1	0-0
Sigmodon hispidus	1-1	0-0	1-4	1-0
Peromyscus leucopus	1-12	0-15	0-11	2-0
Peromyscus gossypinus	0-12	0-6	0-0	0-0
Ochrotomys nuttalli	0-2	0-0	0-0	0-0
Total	57-38	23-25	44-22	20-0
Abundance Index [1]	50-28	33-28	79-15	67-0

[1] Total number of specimens divided by trapnights (X 100) for Sherman or snap traps, or trap months (X 10) for drift fence traps.

Three species of bats, *Pipistrellus subflavus*, *Lasiurus borealis*, and *Nycticeus humeralis* were accounted for in the study areas by shooting. Most were shot on a pipeline through sawtimber. This pipeline created a natural flying corridor and aided in shooting so these bats are not necessarially associated with sawtimber. Specimens of *Plecotus rafinesquii* were located resting under bridges in the study area. The mist netting of bats was unsuccessful.

All other species of mammals except two which should have been captured in longleaf-slash pine stands based on Lowery's (1974) range maps and habitat descriptions were accounted for in the study area. This was done by tracks at scent posts or on dirt roads, animals found dead, or incidental observations. The exceptions were

Table 5. Total number of larger mammals observed by tracks or other means.

Species	Sawtimber	Poles	Saplings	Regeneration
Didelphis virginiana	5	2	1	-
Dasypus novemcinctus	34	2	-	-
Sylvilagus floridanus	1	1	2	4
Sylvilagus aquaticus	1	1	2	4
"rabbits" (tracks)	16	4	1	2
Sciurus carolinensis	1	2	-	-
Sciurus niger	21	2	1	-
"squirrels" (tracks)	26	2	-	-
Glaucomys volans	1	-	-	-
Canus latrans	9	-	1	-
Canus rufus	4	-	-	-
Vulpes fulva	-	1	-	-
Urocyon cinereoargenteus	2	-	-	-
"foxes" (tracks)	8	2	-	-
Procyon lotor	6	-	-	-
Mustela vison	2	-	-	-
Mephitis vison	5	-	-	-
Odocoileus virginianus	28	8	9	1
Totals	170	26	19	11

Mustela frenata and *Reithrodontomys humilis* both of which are thought to be extremely rare in the area. See Table 5 for a list of the larger mammals obtained or observed in the study area.

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Avian Use of Habitats in the Longleaf-Slash Pine Forests of Louisiana

Robert B. Hamilton and Vincent G. Yurkunas

Abstract.--Birds were counted in consecutive plots along transects in four study areas, three grazed and one ungrazed. The differences in abundance, richness and species composition that were found among study areas and seasons were related to habitat differences among areas and the transitory nature of avian communities.

INTRODUCTION

Longleaf pine (*Pinus palustris*)[1] and slash ine (*P. elliottii*) are important commercial species throughout the Southeast (USDA 1965). Toether they are the dominant species in a widepread plant community inhabited by a variety of ildlife species. Except for game birds (Stoddard 931, Stoddard 1963, Rosene 1969, and Holbrook 973) and endangered species (Thompson 1971), litle is known about habitat requirements of birds n "longleaf-slash pine" forests.

The applicability of studies of avian communities in other pine types such as "loblolly" (*P. aeda*) (Noble and Hamilton 1975), "slash" (Johnson nd Landers 1982), "loblolly-shortleaf" (*P. echiata*) (Quay 1947, Johnston and Odum 1956, Dickson nd Segelquist 1977 and 1979), and "pitch pine-ak" (*P. rigida* and *Quercus* spp.) (Conner et al. 979) to bird habitat relationships in the "longleaf-slash" type is not known. Baseline data are eeded by managers on bird habitat relationships or this specific forest type. This study, a part f the USDA Forest Service's Range Evaluation roject to promote sound multiple-use management f southern forested land (Pearson 1979:1), was esigned to provide these baseline data.

The first phase of the study plan was to gather pre-treatment baseline data on soils, water, vegetation, and wildlife. Areas were then to be exposed to varying levels of cattle grazing pressure including an ungrazed control and three grazing intensities. Third, the measures taken in the first phase were to be repeated and the effects of the varying levels of grazing intensity were to be evaluated. This study was to be part of the first phase of the overall investigation.

This approach presupposes that study areas are equivalent with respect to the variables being measured; *i.e.* each study area would initially have the same pattern of distribution and abundance of birds as all of the others and the areas would remain similar throughout time if no treatment were made. This assumption is required for any study that compares the effects of treatments on different areas. However, this assumption apparently does not hold for the areas reported on here. Each study area is unique and consists of a variety of stand ages and types as well as various distributions of these in space. Even management activity varied among the study areas. Birds are not scattered at random and their distribution is not independent of the environment. Because each species has its own requirements, the birds present at any location depend on ambient conditions, and as conditions change the bird communities change (Hamilton and Noble 1975). Species composition and abundance change with succession (Shugart and James 1973, Johnston and Odum 1956) and, particularly relevant in this case, the age of pine stands (Noble and Hamilton 1975). Patterns of abundance are affected by the presence of edge (see Hamilton and Noble 1975) as well as the size of habitat blocks (see Harris 1984). Diversity, a measure that combines the concepts of species richness (number of species) and relative abundances of each species present, is used often to describe avian communities. Diversity changes with succession (see Hamilton and Noble 1975) and is primarily affected by vegetative structure (foliage height diversity) (MacArthur and MacArthur 1961, MacArthur 1964, Schoener 1974). Foliage volume (Balda 1969), percent vegetation cover (Karr and Roth 1971), plant species diversity (Tomoff 1974) and snag density (Conner 1978) have all been shown to affect avian diversity in some situations. Diversity will not be measured directly in this paper (see Hamilton and Lester 1987) but the factors mentioned above should all affect the bird communities in the study areas and the relative abundance of the species that constitute the communities.

We attempted to ascertain whether achievable methods of assessing the composition of bird communities at the study area level can be sufficient for future analysis of treatment effects. In addition, we attempted to determine the desirability of using habitat information that is readily available to foresters, and the general knowledge of habitat requirements of birds to explain any differences of avian abundance patterns among study areas.

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[1] Scientific and common names of plants follow Radford et al. (1968).

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The study areas have endured many years of burning, harvesting, and grazing. Cattle were removed from three of four study areas prior to this study and thus, to a small degree, the effects of cattle grazing can be evaluated in this pretreatment phase by comparing avian communities in the grazed and ungrazed study areas.

Specific objectives are to determine:

1) Seasonal status of birds in the "longleaf-slash" type.

2) Habitat relationships of birds in the "longleaf-slash" type.

3) Differences in avian abundance between grazed and ungrazed study areas.

4) Differences in avian abundance among the ungrazed areas.

We are grateful to those who helped make this study possible. The field work was financed by the U.S. Forest Service and the LSU Agricultural Center and Louisiana Agricultural Experiment Station. Most of the field work was done by Vincent Yurkunas and the data on bird habitat relations were used in his thesis. Dr. Robert E. Noble assisted in the collection of the supplemental vegetation data. Dr. James P. Geaghan and his student, Susan M. Peterman, of the Experimental Statistics Department of Louisiana State University helped with statistical design and programming. We appreciate the help of Forest Service employees, especially Dr. Henry Pearson, who conceived the Range Evaluation Project and provided vegetation data from the study area for our use. The Louisiana Department of Wildlife and Fisheries provided living accommodations near the study area.

STUDY AREA

Four study areas, each approximately 2000 ac in extent, in west-central Louisiana were utilized. Areas 1,2, and 3 are adjacent to each other (n to s) and about 5 mi west of Area 4. Area 3 is approximately 2 mi west of Fullerton (Yurkunas 1984).

The study areas, consisting of flatlands interspersed with gently rolling hills and meandering streams, are in the Vernon Ranger District of the Kisatchie National Forest, Vernon Parish, Louisiana. The forests are primarily the "longleaf-slash pine" type of all ages, with some hardwoods interspersed, especially in the stream bottoms.

Sampling was done along transects that passed through the vegetation sampling points used by Pearson (1979). These points are spaced every 200 ft on n-s lines, 1500 ft apart. The location of the origin of the initial vegetation transect in each study area was randomly determined. Plotless sampling of vegetation had been done previously and prism-recorded trees have been identified and measured with a dbh tape. Plot center have been marked with metal stakes and the adjacent trees have been blazed.

FWe established 75 additional vegetatio points to connect the existing transects in appropriate places to facilitate bird sampling. B adding the additional points, we were able to increase the representativeness of our sample an maintain the desired lengths that were convenien to passable roads. In each study area, two avia sampling transects were placed congruent wit existing vegetation transects, except for interconnecting segments. Avian transects were easily accessible and consisted of a mixture of stan and age types that were representative of th study areas.

Stand-Age Classes

We utilized three stand age classes tha were based on the height of the tallest tree. Th tallest trees in "sapling" plots were 6 m (20 ft or less. The tallest trees in "pole" plots wer between 6 m and 20 m (20 ft to 50 ft) high an those in sawtimber plots were 20 m (50 ft) o more.

Stand Types

We used three stand types based on the percent of prism-recorded trees with a dbh of 1 in o more. "Hardwood" plots had 75% or more hardwoo trees, "pine" plots had 75% or more pine trees and "mixed" plots had less than 75% of each.

Ecological Description

The most abundant trees were longleaf pine slash pine, loblolly pine (*P. taeda*), blackgu (*Nyssa sylvatica*), sweetgum (*Liquidambar styraciflua*), southern red oak (*Quercus falcata*), sweetbay (*Magnolia virginiana*), blackjack oak (*Q. marilandica*), red maple (*Acer rubrum*), and wate oak (*Q. nigra*). Three genera of grasses made u most of the ground cover: *Andropogon*, *Panicum*, an *Paspalum*. The pines were mainly on the ridges an flatlands with the grasses and the two most comm shrubs, waxmyrtle (*Myrica cerifera*) and blackber (*Rubus* spp.) made up the majority of the understory. Hardwoods were mainly in the bottoms an near water.

We considered nine combinations of stan type and age in our study areas as distinct habitats. The study areas consisted of a mixture o interspersed habitats with pine types tending t predominate except near bottoms where hardwoods were more common. The ages and sizes of the interspersed stands depended on past managemen (tab. 1 and fig. 1).

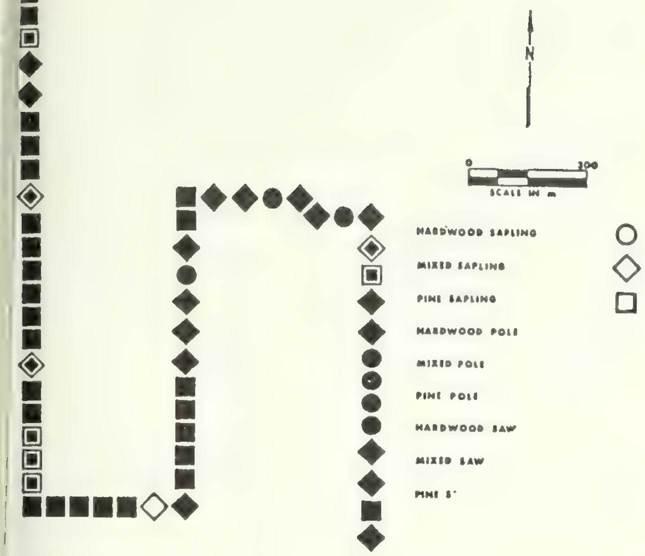

Figure 1.-- Diagrammatic map of habitats on a typical transect, transect 3W, Vernon Ranger District, Kisatchie National Forest, Vernon Parish, Louisiana.

Habitats we identified were

Hardwood Sapling.--These tended to be linear stands located primarily in bottoms where streams crossed or were small blocks isolated in upland pine stands. The saplings were generally close together.

Mixed Sapling.--This habitat was usually found isolated or clumped in upland areas and was unevenly distributed among transects. Trees were generally farther apart than in "hardwood sapling" stands.

Pine Sapling.--Most stands of this habitat were clumped in upland areas but the habitat was sometimes present as a transition between habitats. Trees were spaced farther apart than trees in the preceding habitats. Blackberry thickets were common in this habitat in Area 4.

Hardwood Pole.-- This habitat occurred primarily near stream bottoms, as a transition among habitats. Trees were close together and a vine and hardwood understory was usually present.

Mixed Pole.--This is another habitat that was present at transitions in bottoms but additionally occurred at transitions in upland areas. Trees were farther apart than in "hardwood pole" plots.

Pine Pole.-- Most stands of this habitat were clumped together in upland areas. Trees were spaced close together and the canopy was closed. Ground cover was sparse. Slash pine plantations were often of the age to be assigned to this habitat.

Hardwood Sawtimber.--Most stands of this habitat were clumped along stream bottoms, but a few small stands were in upland areas. Tree density varied among areas. A sparse hardwood and vine understory was present.

Mixed Sawtimber.--Plots of this habitat were located in all segments of the study area. Trees were generally closely spaced. This habitat usually had well developed understory and ground cover layers.

Pine Sawtimber.--This habitat was mostly clumped in uplands and the trees were widely spaced. Ground cover often contained grasses as well as hardwood saplings, shrubs and forbs. This was the most common habitat on the study areas.

Table 1.-- Number of plots in each habitat, by transect, Vernon Ranger District, Kisatchie National Forest, Vernon Parish, Louisiana, 1981-1982

	Transect								
Habitat	1W	1E	2W	2E	3W	3E	4W	4E	Total
Hard sap	1	2	1	0	0	0	1	0	5
Mixed sap	0	1	0	1	1	0	11	0	14
Pine sap	3	21	0	14	0	0	11	8	57
Hard pole	1	1	0	1	0	1	0	0	4
Mixed pole	0	1	0	0	3	1	0	0	5
Pine pole	2	3	0	0	5	5	0	22	37
Hard saw	11	0	9	3	7	8	4	0	42
Mixed saw	12	3	4	7	17	12	4	2	61
Pine saw	30	28	46	34	27	33	29	28	255
Total	60	60	60	60	60	60	60	60	480

The interspersion of habitats along the transects was variable (fig. 1, e. g.). The relative proportions of each habitat differed among transects (tab. 1), but in each area the habitat distribution of the transects roughly approximated the habitat distribution of the corresponding study area. Clumps of some types, such as "hardwood" and "mixed" plots, tended to be relatively small because of their locations at edges or in flood plains of small intermittent streams. These habitats could be considered to be entirely affected by edge (tab. 2). Pine types tended to occur in larger clumps because of the prevailing management practices.

Block size did not vary much with age (tab. 2). Only the pine stands were managed and they were the prevailing type in all of the transects so block sizes of the three stand ages were approximately the same; differences were probably due to sample error.

Table 2.-- Mean number of plots/clump in the habitats of the study areas, Vernon Ranger District, Kisatchie National Forest, Vernon Parish, Louisiana, 1981-1982

	Type			
	Hardwood	Mixed	Pine	Mean
Sapling	1.00	1.75	3.80	2.71
Pole	1.00	1.00	2.85	2.09
Sawtimber	1.62	1.56	4.64	2.98
Mean (study area)	1.46	1.54	4.22	2.82

Table 3.-- Mean number of plots/clump, by age and type, in the four study areas, Vernon Ranger District, Kisatchie National Forest, Vernon Parish, Louisiana, 1981-1982

	Area			
Plot class	1	2	3	4
Sapling	2.55	3.20	1.00	2.82
Pole	1.14	1.00	1.36	7.33
Sawtimber	2.71	2.50	2.54	4.79
Hardwood	1.45	1.27	1.45	2.50
Mixed	1.42	1.20	1.70	1.70
Pine	3.34	4.95	3.18	6.13
Mean	2.45	3.00	2.26	4.29

There were substantial differences among areas, however, both in the relative proportions of each habitat sampled (tab. 1) and in the block sizes of some of the habitats (tab. 3), especially in Area 4 where habitats tended to be larger. Area 4 was separate from the other three Areas and apparently had been managed somewhat differently. Maps of habitat type distribution along each transect have been prepared and are available (Yurkunas 1984:fig. 16-23).

The forests in the region of the study have been managed for "pine sawtimber" for many years. Hardwoods have been excluded through burning. Recreational use is light to moderate, with hunting being the prime recreational activity. Although the study plan was to investigate areas in a pre-grazing situation, Areas 1-3 were being grazed during the study and had been for many years. Grazing pressure was unevenly distributed in time and space. Timber harvesting and thinning were conducted in Areas 1-3 immediately prior to the study. The regeneration method employed is usually seedtree. Prescribed burning is conducted on a 3-yr rotation to stimulate grass growth. During the winter of our study, parts of Areas 1-3 were burned. On Area 4, there was no harvesting, grazing or burning immediately before or during this study, but Area 4 had been grazed up to the year before our study.

METHODS

Transects

We connected some of the vegetation point centers to form eight continuous transects (two/area), each 12,000 ft. long (60 points). Birds were counted as an observer walked the line. Because plot types along the lines were not arranged in a discernible pattern (see fig. 1), the transects were analyzed as a series of consecutive plots, each of a specific type.

Two groups of four transects (one/area) each were randomly selected. These groups were sampled on alternate months. Within a group the order of sampling was random; the direction of travel was alternated throughout the study.

The number of birds/plot was the experimental unit that was analyzed with appropriate tests. The number of birds/plot is a density index rather than a true density (Caughley 1977). All birds were probably not detected and the true density is thus somewhat higher than we report.

We estimated that we could hear and see the birds present at a distance of 75 m (246 ft) and used this distance as the distance from the transect line to the plot boundary. Total plot width was thus 150 m (500 ft). The length of each plot was 200 ft, and each plot had an area of 2.3 acres. The vegetative sampling points were the centers of each plot, and vegetation at the center was attributed to the entire plot.

Sampling Seasons

We divided the year into 6 seasons for this analysis:

1) January-February, winter with little migration;

2) March April, bulk of spring migration and residents begin breeding;

3) May-June, peak of resident breeding and late spring migration;

4) July-August, post-breeding dispersal and early fall migrations;

5) September-October, peak of autumn migration;

6) November-December, primarily late fall migrants and wintering birds present.

For statistical tests, the relatively stable seasons "1", winter, and "3", breeding were used.

Stistical Methods

Density (#/plot) of birds was analyzed as a dendent variable as were species richness and andance. Season, stand type, stand age, transt, and study area were the independent variaes. We compared species richness, abundance, ad density among areas with an Analysis of Variace and Duncan's Multiple Range Test (Steele and Trie 1980).

To make comparisons among habitats we used a ltivariate analysis of variance (MANOVA) using a del with a factorial arrangement for stand type d stand age and a split-plot arrangement for ason. Alpha was 0.05 when we tested for all the ecies lumped together. Alpha of 0.1 was used en testing individual models because of the relively small sample sizes involved.

Computations were made, using programs from e Statistical Analysis System (SAS) (Helwig and uncil 1979), on an IBM 3033 Computer at the stems Network Computer Center, Louisiana State iversity,

ield Methods

Birds were counted along the selected tranect from dawn to about 30 minutes later. Binoclars were used to aid visual identification. All irds that were detected (singing, nesting, oraging, etc,) within an estimated 75 m (250 ft) f the transect lines were counted. The appropri te sample plot, for those birds not perpendicular o the transect line, also had to be determined. hree minutes were allowed to traverse each plot. o counts were made when it was raining. It took pproximately 3 hrs. to sample each transect.

RESULTS AND DISCUSSION

eather

The mean maxima and minima temperatures in he summer of 1981 were about 2½F warmer than average (tab. 4). There was only 1 day, in July 981, with a maximum exceeding 100½ F. Most of he study period was also drier than usual (tab.).

bundance

A total of 83 species were found on the tudy areas. The density of the 73 species that ere found during the counting periods included n this report varied greatly among species and tudy areas. (tab. 5). The most abundant species as the Yellow-rumped Warbler (scientific names or all species not given elsewhere are listed in ab. 5), with a maximum density of 100/100 plots n Area 3 in the winter. Next was the American obin with a maximum density of 79.6/100 plots in rea 1 in the winter. Both species are flocking pecies and are often quite abundant. In the breeding season the highest density was 16.7/100 plots for Northern Cardinals in Area 3. Next was 15.0/100 plots for Blue Jay also in Area 3. There were many species found only occasionally in both seasons (tab. 5). A species that was surprisingly abundant was Bachman's Sparrow with densities from 7.9 to 12.5/100 plots during the breeding season. This species is rather inconspicuous, except for when it is singing, and lower observed winter densities were probably due to the lack of singing at that time. Many ornithologists consider the Bachman's Sparrow to be rare and a threatened species. The endangered Red-cockaded Woodpecker was relatively common in all seasons. All other species were as expected except densities were much lower than in the corresponding study in the "loblolly, shortleaf pine-upland hardwood" forests to the east (Hamilton and Lester 1987).

Table 4.-- Weather data at Leesville, Louisiana, approximately 33 km NW of the study areas, for the period 19511973 (NOAA 1975) and for the study period, Jul.1981-Jun.1982 (Ruffner 1980)

	Mean daily Max. (°C)		Mean daily Min (°C)		Mean precipitation (cm)	
Month	Avg	Study	Avg	Study	Avg	Study
Jul	92.8	94.5	69.8	72.0	5.28	4.67
Aug	92.7	94.9	68.7	70.3	3.70	1.20
Sept	88.5	89.3	64.0	61.5	3.66	2.36
Oct	80.8	78.5	52.5	56.0	2.99	4.99
Nov	70.0	73.3	44.2	47.3	4.13	2.71
Dec	62.8	60.4	39.6	36.9	5.98	2.75
Jan	60.8	61.9	37.9	37.4	4.21	2.61
Feb	64.2	59.0	39.9	37.9	4.76	4.84
Mar	71.1	˜1.9	45.9	52.8	4.21	3.35
Apr	78.6	74.7	54.9	54.4	5.20	6.50
May	84.7	85.2	60.6	60.6	5.16	4.01
Jun	90.5	91.5	66.7	68.0	4.17	5.22

The number of individuals in summer and winter was highest in Area 3 and second highest in Area 4 (tab. 6). This was probably due to the habitat differences among the areas (tab. 1). Area 3 had more "hardwood" and "mixed sawtimber" plots than the other areas. These types had well-developed understory and ground cover layers as well as high vegetational diversity. The shrub and ground cover layers in Area 4 were more developed in each plot type than in other areas because of the lower intensity of management and the lack of grazing. Abundance was higher in winter than in summer. Differences in abundance among areas were larger in the summer than in the winter. This is as expected because mobility of birds is reduced in summer due to nesting and increased in winter as flocks move from place to place.

Ten species were found in the study but not during the periods covered in table 5.

Common Name2[2]	Scientific name
Broad-winged Hawk	*Buteo platypterus*
American Woodcock	*Scolopax minor*
Barred Owl	*Strix varia*
Eastern Screech-Owl	*Otus asio*
Chuck-will's-widow	*Caprimulgus carolinensis*
Winter Wren	*Troglodytes troglodytes*
Sedge Wren	*Cistothorus platensis*
Black-and-white Warbler	*Mniotilta varia*
Rose-breasted Grosbeak	*Pheucticus ludovicianus*
Eastern Meadowlark	*Sturnella magna*

Species Richness

Species richness did not differ as much as abundance among areas (tab. 6). Species richness would be affected by the habitat variety among the areas and we attempted to make that similar (tab. 1). However, when richness/plot (a type of diversity) was tested among areas, similar patterns held as for number of individuals (tab. 6 Because all areas had good mixes of habitats th would attract a variety of species but Areas 3 a 4 had more of the highly stratified habitat typ and should have higher diversities (tab. 1) a Areas 3 and 4 had higher richness/plot (tab. 6 the importance of vegetational structure reinforced.

Composition and Relative Density

Seventeen species were common to all are in the summer (tab. 5). The number of speci exclusive to an area in the summer varied fr none in Area 2 to five in Area 3 (tab. 5). In t winter, the number of exclusives ranged from in Area 2 to five in Area 4 (tab. 5). Again t community is affected by larger habitat comple ity in areas 3 and 4; sampling error may also ha contributed to these patterns.

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[2] Common and scientific names of birds are from the AOU Check-list (1983)

Table 5.--Density values (#/100 plots) for 73 species of birds on four study areas in summer 1981 and winter 1982

Common Name	Scientific Name	Summer 1981				Winter 1982			
		Area 1	Area 2	Area 3	Area 4	Area 1	Area 2	Area 3	Ar 4
Cattle Egret	*Bubulcus ibis*	0.4	---	---	---				
Wood Duck	*Aix sponsa*					---	---	0.4	--
Black Vulture	*Coragyps atratus*	0.4	---	---	0.8	---	---	2.1	7.
Turkey Vulture	*Cathartes aura*	---	---	0.4	---	0.8	---	0.4	0.
Red-shouldered Hawk	*Buteo lineatus*	---	---	0.4	---				
Red-tailed Hawk	*Buteo jamaicensis*					0.4	0.4	---	0.
American Kestrel	*Falco sparverius*	0.4	1.7	---	0.4	---	---	---	0.
Northern Bobwhite	*Colinus virginianus*	---	1.2	3.3	3.3	4.6	---	---	--
Mourning Dove	*Zenaida macroura*	---	0.8	1.7	6.7	---	---	0.4	2.
Yellow-billed Cuckoo	*Coccyzus americanus*	1.7	1.2	3.3	1.2				
Common Nighthawk	*Chordeiles minor*	0.4	---	---	0.8				
Chimney Swift	*Chaetura pelagica*	1.2	1.7	---	0.8				
Red-headed Woodpecker	*Melanerpes erythrocephalus*	0.4	1.2	---	1.2				
Red-bellied Woodpecker	*Melanerpes carolinus*	---	2.1	5.0	3.8	0.8	2.5	2.5	1.
Yellow-bellied Sapsucker	*Sphyrapicus varius*					1.2	---	0.8	0.
Downy Woodpecker	*Picoides pubescens*					---	---	0.4	--
Hairy Woodpecker	*Picoides villosus*	---	---	0.8	---				
Red-cockaded Woodpecker	*Picoides borealis*	1.7	3.3	1.2	2.9	3.3	2.1	0.8	2.
Northern Flicker	*Colaptes auratus*	0.8	2.9	4.6	4.2	---	3.3	2.5	2.
Pileated Woodpecker	*Dryocopus pileatus*	0.4	0.4	---	---	---	0.8	---	--
Eastern Wood-Pewee	*Contopus virens*	0.8	0.4	4.2	2.5				
Acadian Flycatcher	*Empidonax virescens*	0.8	0.4	5.4	---				
Eastern Phoebe	*Sayornis phoebe*					2.1	0.4	1.2	0.
Great Crested Flycatcher	*Myiarchus crinitus*	2.1	2.1	5.4	2.5				
Eastern Kingbird	*Tyrannus tyrannus*	0.4	---	2.1	5.8				
Purple Martin	*Progne subis*	0.4	---	---	1.2				
Barn Swallow	*Hirundo rustica*	---	---	0.4	0.4				
Blue Jay	*Cyanocicta cristata*	7.1	7.9	15.0	7.5	0.4	---	0.4	1.
American Crow	*Corvus brachyrhynchos*	2.5	---	---	2.9	---	---	0.8	1.
Carolina Chickadee	*Parus carolinensis*	5.0	2.9	3.8	5.0	3.8	5.8	6.7	4.
Tufted Titmouse	*Parus bicolor*	4.2	3.8	7.9	0.8	1.7	2.1	3.3	0.
Red-breasted Nuthatch	*Sitta canadensis*					0.4	---	---	--
White-breasted Nuthatch	*Sitta carolinensis*					0.4	---	---	--

ble 5.--Density values (#/100 plots) for 73 species of birds on four study areas in summer 1981 and winter 1982--Continued

mmon Name	Scientific Name	Summer 1981 Area 1	 Area 2	 Area 3	 Area 4	Winter 1982 Area 1	 Area 2	 Area 3	 Area 4
own-headed Nuthatch	*Sitta pusilla*	2.1	8.3	8.8	10.0	8.3	5.0	11.2	18.8
own Creeper	*Certhia americana*					0.4	2.5	---	---
rolina Wren	*Thryothorus ludovicianus*	5.4	8.3	9.6	5.4	0.8	5.4	1.2	2.5
lden-crowned Kinglet	*Regulus satrapa*					3.3	0.8	5.0	---
by-crowned Kinglet	*Regulus calendula*					11.7	7.9	11.7	6.7
ue-gray Gnatcatcher	*Polioptila caerulea*	0.8	1.2	2.5	---				
stern Bluebird	*Sialia sialis*	0.8	0.8	3.3	1.7	1.2	3.8	5.0	2.9
rmit Thrush	*Catharus guttatus*					1.2	0.4	0.4	---
od Thrush	*Hylocichla mustelina*	0.8	1.7	3.3	---				
erican Robin	*Turdus migratorius*					79.6	49.6	65.8	34.2
ay Catbird	*Dumetella carolinensis*	---	---	0.4	---	---	---	---	0.4
rthern Mockingbird	*Mimus polyglottos*	---	---	0.8	0.8				
own Thrasher	*Toxostoma rufum*	---	0.4	0.4	---				
dar Waxwing	*Bombycilla cedrorum*					2.1	13.3	20.0	7.1
ite-eyed Vireo	*Vireo griseus*	0.4	2.1	3.8	1.7				
llow-throated Vireo	*Vireo flavifrons*	---	0.4	0.8	---				
d-eyed Vireo	*Vireo olivaceus*	0.4	---	3.8	---				
ange-crowned Warbler	*Vermivora celata*					---	0.4	0.4	---
llow rumped Warbler	*Dendroica coronata*					48.3	54.6	100.0	0.97.1
llow-throated Warbler	*Dendroica dominica*	---	---	0.8	---				
ine Warbler	*Dendroica pinus*	3.8	4.6	6.7	3.3	5.0	7.9	5.4	5.8
rairie Warbler	*Dendroica discolor*	0.8	---	---	---				
mmon Yellowthroat	*Geothlypis trichas*	---	---	---	3.8				
oded Warbler	*Wilsonia citrina*	0.8	0.8	4.6	---				
ellow-breasted Chat	*Icteria virens*	1.2	---	0.4	7.1				
ummer Tanager	*Piranga rubra*	3.8	2.5	7.9	2.5				
orthern Cardinal	*Cardinalis cardinalis*	1.0	9.2	16.7	6.2	2.1	1.2	3.8	0.8
lue Grosbeak	*Guiraca caerulea*	0.8	---	0.8	1.2				
ndigo Bunting	*Passerina cyanea*	0.8	---	---	---				
ufous-sided Towhee	*Pipilo erythrophthalmus*	0.4	---	---	5.8	---	---	---	2.5
achman's Sparrow	*Aimophila aestivalis*	8.8	12.1	7.9	12.5	2.5	5.0	0.4	5.0
hipping Sparrow	*Spizella passerina*	1.7	2.9	3.3	2.9	4.6	6.7	1.7	2.5
ield Sparrow	*Spizella pusilla*	0.4	---	---	---	0.8	---	---	---
ong Sparrow	*Melospiza melodia*					---	---	---	2.1
wamp Sparrow	*Melospiza georgiana*					---	---	---	2.5
hite-throated Sparrow	*Zonotrichia albicollis*					2.9	0.4	2.1	2.9
ark-eyed Junco	*Junco hyemalis*					2.9	0.8	0.4	6.2
rown-headed Cowbird	*Molothrus ater*	0.8	---	2.1	1.2	---	---	16.7	---
rchard Oriole	*Icterus spurius*	2.1	---	0.4	3.3				
merican Goldfinch	*Carduelis tristis*					1.2	8.8	54.6	1.7

Table 6.-- Numbers of species, species per plot, individuals, and individuals per plot for Areas 1-4, Kisatchie National Forest, Vernon Parish, Louisiana, in summer and winter, 1981-1982

	Species			Individuals		
	#	#/plot	Gp	#	#/plot	Gp
SUMMER						
Area 1	40	0.67	-A	188	0.78	-A
Area 2	30	0.76	-A	215	0.90	-A
Area 3	39	1.35	-B	370	1.54	-B
Area 4	36	1.05	-C	299	1.05	-C
F-values		21.310			15.297	
p		0.005			0.005	
WINTER						
Area 1	30	0.70	-A	478	1.99	-A
Area 2	26	0.79	-A	461	1.92	-A
Area 3	32	0.99	-B	789	3.29	-B
Area 4	32	1.09	-B	547	2.28	-AB
F-values		6.441			2.794	
p		0.005			0.050	

[1] Within a season, numbers followed by the same letters are not significantly different from each other (ANOVA and Duncan's Multiple Range test, P<0.05)

The relative densities of 18 species varied among areas in the summer (tab. 7). The species that were more common in Area 3 (Acadian Flycatcher, Blue Jay, Red-eyed Vireo, Hooded Warbler, Summer Tanager, and Northern Cardinal) are all species of the canopy or sub-canopy of "hardwood" or "mixed" forests. Those species preferring Area 4 (Eastern Kingbird, Common Yellowthroat, Yellow-breasted Chat, and Rufous-sided Towhee) are birds of the understory (kingbirds perch on top of low vegetation) and most prefer thick undergrowth. These data support the habitat hypotheses mentioned earlier.

In the winter, relative densities of eight species differed among areas (tab. 8). Habitat differences, thus, do not seem to be as pronounced in the winter as the summer. The reasons why some species prefer some areas in the winter are more varied than the reasons for preferences in the summer. Swamp Sparrows and Song Sparrows prefer Area 4 and utilize brushy, shrubby undergrowth. Yellow-rumped Warblers were most abundant on Areas 3 and 4 and utilize a well-developed midstory. The nuthatches were more prevalent in Area 4 because of the many "pine pole" plots there. Brown-Creepers prefer large trees and there was more sawtimber on Area 2 (tab. 1)

Table 7.-- Statistics for species wi significant differences in relati density among study areas, Kisatch National Forest, Vernon Paris Louisiana, in summer, 1981-1982

			Area			
Species	F	p	1	2	3	
Northern Bobwhite	3.095	0.050	A[1]	AB	B	
Mourning Dove	5.244	0.005	A	A	A	
Red-bel. Woodpecker	4.346	0.005	A	AB	B	
Eastern Wood-Pewee	3.381	0.025	A	A	B	A
Acadian Flycatcher	9.562	0.005	A	B	A	
Eastern Kingbird	6.500	0.005	A	A	A	
Blue Jay	2.842	0.050	A	A	B	
Tufted Titmouse	4.614	0.005	AB	AB	A	
Wood Thrush	3.062	0.050	A	AB	B	
White-eyed Vireo	2.368	0.100	A	AB	B	A
Red-eyed Vireo	6.583	0.005	A	A	B	
Common Yellowthroat	7.727	0.005	A	A	A	
Hooded Warbler	6.733	0.005	A	A	B	
Yellow-breasted Chat	10.480	0.005	A	A	A	
Summer Tanager	3.950	0.010	A	A	B	
Northern Cardinal	3.605	0.025	A	A	B	
Rufous-sided Towhee	11.529	0.005	A	A	A	
Orchard Oriole	3.562	0.025	AB	A	A	

[1] Determined by using ANOVA and Duncan's Multip Range test (P<0.050); areas having the same lett are not significantly different.

Table 8.-- Statistics for species wi significant differences in relati density among study areas, Kisatch National Forest, Vernon Paris Louisiana, in winter, 1981-1982

			Area		
Species	F	p	1	2	3
Brown-headed Nuthatch	4.74	0.005	A[1]	A	A
Brown Creeper	3.78	0.025	A	B	A
Carolina Wren	3.22	0.025	A	B	A
Yellow-rumped Warbler	3.92	0.010	A	A	B
Bachman's Sparrow	3.81	0.010	AB	A	B
Song Sparrow	2.89	0.050	A	A	A
Swamp Sparrow	3.08	0.050	A	A	A
American Goldfinch	3.07	0.050	A	A	B

[1] Determined using ANOVA and Duncan's Multip Range test (P<0.050); areas having the same lett are not significantly different.

Species Habitats

The habitat utilization patterns of species that were found more than 14 times we tested. Out of the 83 species encountered, 40 the numerical abundance criterion and *in* tc accounted for about 95% of the bird observatior

tested all nine habitats and consequently sam-
e sizes were often not large enough to allow
gnificant differences to be detected. The pat-
rns found usually were in agreement with what is
iown about the habitats of each bird species in-
lved. Significantly different stand type, and
and age preferences for the 40 species shown in
ible 9 are underlined.

ible 9.-- Seasonal status, stand type and age preferences of the 40 most abundant bird species observed in the study areas, Vernon Ranger District, Kisatchie National forest, Vernon Parish, Louisiana, 1981-1982

Species	Seasonal status[2]	Preference[1] St type	St age
lack Vulture	PR	M	4
orthern Bobwhite	PR	H	3
ourning Dove	PR	H	4
ellow-billed Cuckoo	SR	M	4
ed-headed Woodpecker	UN	P	3
ed-bellied Woodpecker	PR	M	4
ed-cockaded Woodpecker	PR	M	3
orthern Flicker	PR	H	4
astern Wood-Pewee	SR	M	2
cadian Flycatcher	SR	M	3
reat Crested Flycatcher	SR	H	3
astern Kingbird	SR	P	2
lue Jay	PR	M	2
merican Crow	PR	P	4
arolina Chickadee	PR	M	3
Tufted Titmouse	PR	M	2
Brown-headed Nuthatch	PR	P	4
Carolina Wren	PR	H	3
Golden-crowned Kinglet	WR	M	4
Ruby-crowned Kinglet	WR	M	3
Blue-gray Gnatcatcher	SR	M	4
Eastern Bluebird	PR	M	2
Wood Thrush	SR	H	4
American Robin	WR	P	4
Cedar Waxwing	WR	M	3
White-eyed Vireo	SR	H	3
Yellow-rumped Warbler	WR	P	2
Pine Warbler	PR	P	3
Hooded Warbler	SR	M	4
Yellow-breasted Chat	SR	P	2
Summer Tanager	SR	H	3
Northern Cardinal	PR	M	3
Rufous-sided Towhee	PR	H	2
Bachman's Sparrow	PR	M	2
Chipping Sparrow	PR	P	4
White-throated Sparrow	WR	H	2
Dark-eyed Junco	WR	M	2
Brown-headed Cowbird	PR	M	4
Orchard Oriole	SR	M	2
American Goldfinch	WR	P	3

[1] PR = permanent resident, SR = summer resident, WR = winter resident, UN = unknown.

[2] Stand type preferences: H = Hardwood, M = Mixed, P = Pine; Stand Age preferences: 2 = Sapling, 3 = Pole, 4 = sawtimber.

In some cases, seasonal behavioral changes as well as sample error can contribute to unexpected patterns. Thus, the Red-cockaded Woodpecker is a permanent resident but its apparent abundance varied within the year in a way not directly related to density changes brought about by mortality or natality. Its habitat utilization changed seasonally between pole and sawtimber stands (fig. 2). We over-sampled pole plots, especially slash pine plantations; they were rare in the study area, but because we wanted to know what birds were using them we included them in our transects where possible. Any species that preferred "pine-pole" stands would have an apparently higher density than one utilizing "pine sawtimber" and the estimated density of the Red-cockaded Woodpecker thus shifted as its habitat preferences shifted.

We analyzed the habitat relations and prepared figures to graphically depict the habitat usage of the 40 most common species and will comment on several of them here. All can be found in Yurkunas (1984).

Density of all birds together differed significantly among seasons, utilization of stand types and ages varied seasonally, utilization of stand ages varied seasonally, and density varied among transects.

Mourning Dove.--Density of Mourning Doves differed significantly among transects ($p < 0.0628$). This species feeds in grasses and the ground cover of grasses seemed much more extensive in the ungrazed Area, Area 4.

Red-cockaded Woodpecker.--Surprisingly, Red-cockaded Woodpeckers were encountered at higher densities in pole plots than in sawtimber ones (fig. 2). This species was especially conspicuous before and after the breeding season and had a significantly different abundance between seasons ($p < 0.0342$). It is a social species so often clans or family groups were encountered. Any encounters of a group in pole plots greatly affected the mean density because of the scarcity of pole plots on the transects.

Acadian Flycatcher.--The density of this species varied among transects ($p < 0.0671$) and was highest in the clumped "hardwood" and "mixed" plots concentrated in the stream bottoms of transect 3E. The habitat utilization pattern (fig. 3) was affected by structure and the lack of resolution in our habitat classification. This species utilizes hardwood midstory trees 20-40 ft high and often located near water (Hamel et al. 1982). In the "mixed pole" stands these were predominantly canopy trees and in "hardwood sawtimber" stands they were in the subcanopy.

Tufted Titmouse.--Tufted Titmice prefer mixed and hardwood plots (tab. 4) and used the habitat differently among seasons types and seasons ($p<0.0066$) (fig. 4). It was never found in "pine pole" plots.

White-eyed Vireo.--Density shifts of this species varied seasonally among habitats ($p < 0.0003$) (fig. 5). The shifting patterns of habitat utilization of this species well illustrates the complexities of trying to characterize habitats.

Yellow-rumped Warbler.--This species is a winter resident (tab. 9) that seems to utilize all habitats extensively (fig. 6).

Yellow-breasted Chat.--Chats are summer residents (tab. 9) that almost exclusively occupy "sapling" stages except during spring migration when they can be found in "mixed pole" habitats (fig. 7).

Rufous-sided Towhee.--Towhees prefer hardwood and sapling plots (tab. 9), but show an interesting seasonal pattern of occupying "mixed sapling" plots at all seasons except during the breeding season (fig. 8).

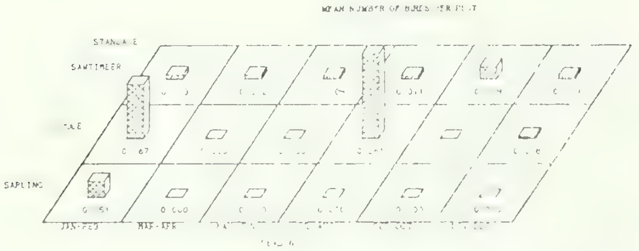


Figure 2.-- Density of Red-cockaded Woodpeckers by stand age and season.

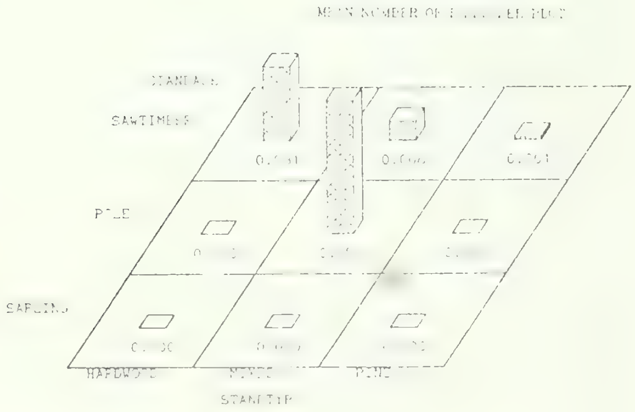


Figure 3.-- Density of Acadian Flycatchers by stand type and stand age.

SUMMARY

Seasonal and habitat relations, with respect to nine stand-age combinations, of 73 species of birds are described for the longleaf-slash pine forests of west-central Louisiana. The information presented conforms to that available in the literature except that shifts in stand-age preference with season were noted.

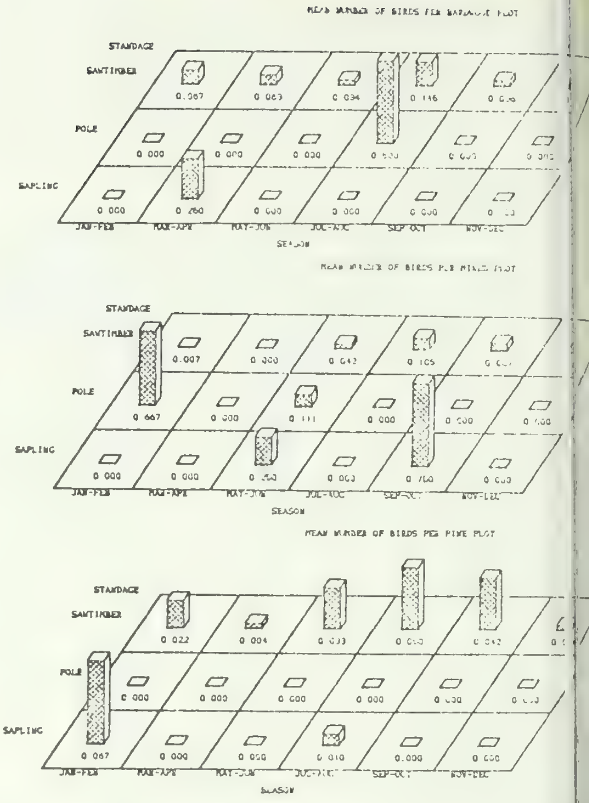


Figure 4.-- Density of Tufted Titmice by st type, stand age, and season.

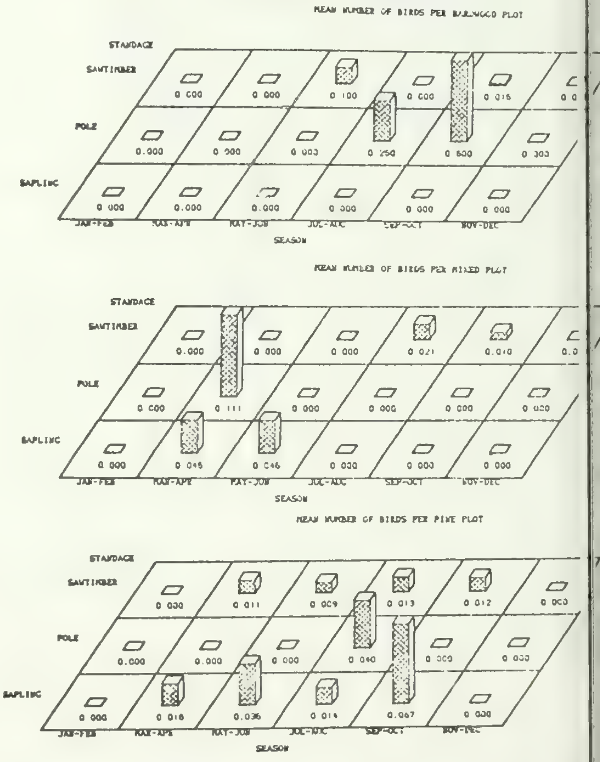
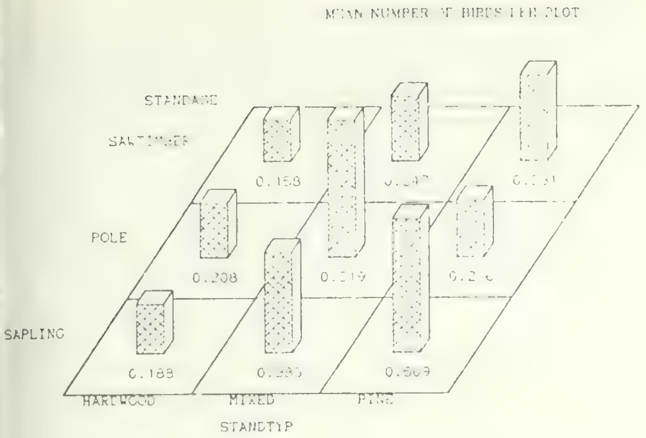


Figure 5.-- Density of White-eyed Vireos by sta type, stand age, and season.



igure 6.-- Density of Yellow-rumped Warblers by stand type, and stand age.

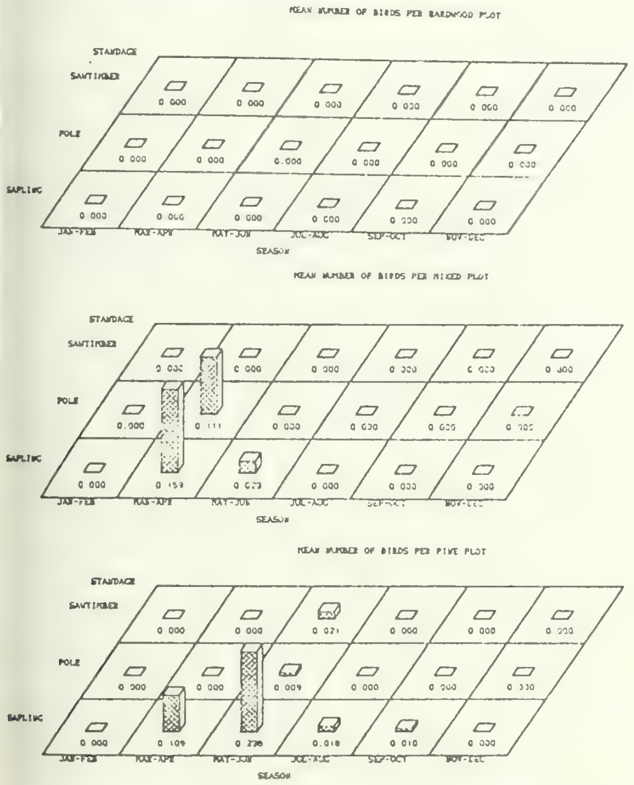


Figure 7.-- Density of Yellow-breasted Chats by stand type, stand age, and season.

The four study areas differed in the relative proportions of the nine habitat types in the avian transects as well as the mean size of the habitat clumps. Management was different in Area 4 than in the other three areas. Area 4 was the only ungrazed area and some of the management differences among areas, such as time since the last controlled burn, may have been related to the difference in grazing practices. Subjectively, we felt that vegetation structure was noticeably different in the ungrazed Area 4. Unfortunately the vegetation measurements were taken prior to our study when grazing was still occurring on Area 4. The differences noted were so obvious, however, that it reinforces the concern that many have about the possible effects of grazing.

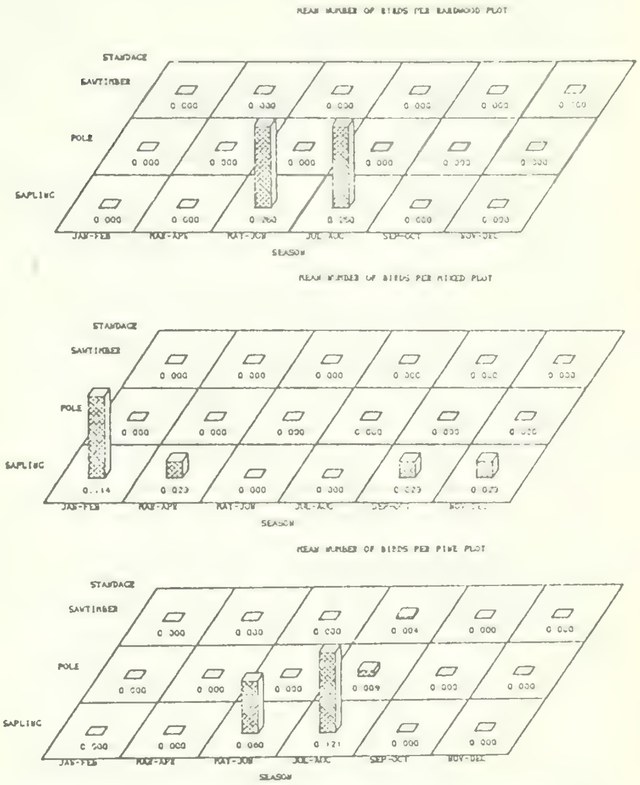


Figure 8.-- Density of Rufous-sided Towhees by stand type, stand age, and season.

Density varied from a high of 100 birds/100 plots for the American Robin in winter to a low of 0.4/100 plots for many species. There were significant differences in numbers of individuals among areas (even among the grazed areas) as well as significant differences in the mean number of species/plot (a type of diversity). The grazed Area 3 and the ungrazed Area 4 held the most individuals and the most species/plot. These differences were due to structural differences among areas. Structural differences in Area 4 were related to the lack of grazing and those in Area 3 were due to a disproportionate number of the complex "hardwood" and "mixed" habitat types. Abundance differences were more pronounced in the summer than in the winter.

Species that occurred exclusively in one area were again concentrated in Areas 3 and 4.

Densities varied among areas in ways that corresponded to the known habitat requirements of the birds involved and the structural differences among the areas.

Habitat utilization patterns were tested specifically for the 40 most common species. Even though sample sizes were low, statistical differences were found for 20 species. Again these differences corresponded with the structure of the vegetation and the known habitat requirements of the birds. The complexity of any future experimental design and analysis is increased because utilization patterns change seasonally. There were many differences found in avian utilization among the areas that were related to habitat structure and complexity. Because of this it would not be possible to compare areas with different treatments in the future unless the areas were perfectly matched in habitat composition, which is extremely unlikely.

The ungrazed area seemed to be structurally different than the other areas in the quantities of ground and shrub vegetation and there were corresponding changes in avian usage. These changes were apparent even though grazing had occurred up to 2 years prior to our study. Some of the structural differences were apparently related to a difference in the amount of control burning on the areas. We do not know if this difference was related directly to cattle grazing or not.

The structure of the vegetation governs the diversity of birds present to a great extent. Any management change that modifies structure will modify the avian community. The desirability of any changes must be evaluated by the manager but changes can be predicted if structural changes are known.

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CROSS-COUNTRY TRACK STATIONS FOR INDEXING WILDLIFE POPULATIONS

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Abstract: Track stations were systematically deployed over 4 range units (about 225 ha each) of the Palustris Experimental Forest in central Louisiana. Track frequencies for small, exclusively resident wildlife increased significantly from spring to fall and track frequencies of cattle were associated with changes made in cattle numbers during the study period. Cross-country track sampling provides a means to monitor wildlife populations on relatively small, roadless tracts of forested land and provide land managers a means to monitor species presence and changes in animal populations or activity levels.

Southern forests are valued as habitat for a variety of wildlife species. Proper management can not take place without knowing how wildlife populations respond to management practices. However, wildlife population densities vary naturally among localities and influences of different land uses are difficult to measure (Johnson 1982). Scientific management of game is possible only when changes in populations can be monitored; thus improved measures of relative population densities are badly needed.

Track stations are a population indicator that can be deployed over large areas and can provide useful indices for comparing population densities with little effort compared to mark-recapture methods (Linhart and Knowlton 1975). Track stations can be used to simultaneously index a variety of species. The traditional procedure is to establish track stations (or scent stations) along secondary roads; however, this may not effectively sample the land area without bias. In addition, availability and distribution of secondary roads usually differs among areas. Population indices used for monitoring changes over regions, such as track counting or nightlighting along roads, are not useful for monitoring populations on small blocks of land, which are often essentially roadless. Further, use of off-road vehicles is often restricted in forested habitat. A population indexing method is needed that is relatively simple, inexpensive in cost and time, requires little technical expertise, and can be used on relatively small, roadless tracts of forested habitat. The technique should be unaffected by preconceptions as to the relative abundance of wildlife on an area.

In theory, there is a relationship between track densities and population densities of wildlife (Caughley 1977). For example, populations of rabbits (Sylvilagus spp.) generally increase by 300% to 500% from spring to fall (Allen 1954) and their track densities may increase similarly. However, field testing of this relationship is difficult. The objective of this study was to examine the utility of cross-country deployment of track stations for monitoring wildlife population densities in southern pine forests.

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he U. S. Man and the Biosphere Program (MAB-3) upporting management of grazing lands.

TUDY AREA

This study was conducted from February hrough October 1982 on the Palustris xperimental Forest in central Louisiana. econd growth longleaf pine (Pinus palustris), nd planted stands of slash (P. elliottii) and loblolly (P. taeda) pines existed on the area. our forested range units varying from 218 to 39 ha were studied. Range units (Northeast-NE, orthwest-NW, Southwest-SW, and Southeast-SE) ere used for cow-calf operations and stocked ith 19, 29, 32, and 32 cows with 16, 27, 29, nd 28 calves born from December through March, espectively. Calves remained with the cows ntil mid-August. One bull serviced each herd rom February 20 through July 1, 1982. Cattle were removed from the NE range unit during the uly sampling period.

Understory vegetation on the area was primarily bluestem grasses (Andropogon spp., Schizaskyrium spp.) and other herbaceous plants (Clary 1979, Johnson and Pearson 1981). Shrubs were not abundant due to a long history of prescribed burning. About one-third of each grazing unit was rotationally prescribed burned each winter to remove rough cover and provide green forage for early spring grazing. Topography of the area is flat with slight relief.

METHODS

During winter of 1981-1982, 10 transects were established on each of the four range units. On 3 units, transects were located about 140 m apart and track stations were deployed at 160 m intervals along each transect for a total of 100 stations per unit. Track stations on the other unit were deployed at 80 m intervals for a total of 200 stations. To reduce influences from surrounding land, no track station was placed closer than 80 m from the range unit boundary.

Track stations were established by removing sod and vegetation from a 1 m^2 area with a potato rake. During the sampling periods (February-May, July, and October, 1982), soil was raked on each station to provide loose soil for recording tracks of animals. All 500 stations were prepared during the same day, and tracks were recorded during the following day. The presence or absence of tracks was recorded for each station and results were expressed as percent frequency of occurrence for each species identified.

The application of frequency sampling for comparing relative population densities of animals has been described by Caughley (1977). There is a direct relationship between relative track frequencies and relative track densities. The relationship between frequency and density of tracks is described by:

$$F = 1 - e^{-d},$$

where F is frequency of plots with track occurrence divided by the total plots sampled, e is the natural logarithm, and d is track density. Under the assumption that animals were distributed at random over the grazing units, the relationship was used to estimate track densities (number (n)/ha) for each species recorded on track stations.

Although there are presently few published reports, most investigators use a scent to attract predators to stations (Brady 1978, Morrison 1981, Knowlton and Tzilkowski 1979, Hon 1979). The widespread interest in the use of scented stations was probably stimulated by the 17-state study on coyote density reported by Linhart and Knowlton (1975). However, responses of different wildlife to scents vary. Some species seem attracted to scent while others seem repelled (Bullard et al. 1978, Roughton and Bowden 1979, Turkowski et al. 1979). During February and May sampling periods, we compared results from unscented stations to results from stations scented with a liquid made from fermented eggs (Bullard et al. 1978). About 1 ml of scent was placed on the soil in the middle of alternate stations after raking. Responses to scented and unscented stations were evaluated using chi-square procedures where the expected relative track frequency of occurrence was 50% of the total responses for each species recorded.

We had no previous knowledge as to how track densities vary among days. During July, we recorded tracks for 3 days in 2 units to estimate average track densities and variation among track densities for each grazing unit. The purpose was to determine how many days of sampling might be required to obtain data for statistically comparing animal densities among grazing treatments. We used the sample standard deviations to estimate the number of sampling days needed to determine statistical differences at specific confidence levels.

The 4 range units were used as replicates for the study. Track densities for each wildlife species were averaged among units and compared between seasons by Student's t tests. Track densities were averaged among days for the July samples and differences among range units were statistically evaluated with Student's t tests. We assumed that the average change in rabbit (Sylvilagus floridanus and S. aquaticus) population density from spring to fall would significantly increase and tested the hypothesis that relative track densities reflected this expectation.

Because cattle populations were known, we compared their track densities among range units and seasons to determine whether relative track densities reasonably reflected relative differences in population densities. The relationship between populations of cattle and cattle track densities was evaluated with linear regression procedures.

RESULTS

Wet soil conditions limited the use of some track stations, but from 75% to 90% of the stations were usable during each sampling period. Tracks recorded on stations were from cattle and 11 wildlife taxa: armadillo (*Dasypus novemcinctus*), rabbits, white-tailed deer (*Odocoileus virginianus*), squirrels (*Sciurus* spp.), raccoon (*Procyon lotor*), opossum (*Didelphis virginianus*), bobcat (*Lynx rufus*), coyote (*Canis latrans*), foxes (*Urocyon cinereargenteus* and/or *Vulpes vulpes*), bobwhite (*Colinus virginianus*), and wild turkey (*Meleagris gallopavo*). Wildlife track densities in the grazing unit with 200 track stations were similar to track densities in the 3 units with 100 stations each. Bobcat tracks occurred only on scented track stations and none of the species were affected by scent (Table 1). Predators generally respond to scent but since the bobcat densities represent only 3 occurrences, these data are inconclusive regarding their influence.

Table 1. Track densities for animals on the Palustris Experimental Forest compared between scented and unscented stations for February and May 1982.

Species	Scented[1/] (399)[2/]	Unscented (447)
Cattle	0.055	0.083
Armadillo	0.043	0.056
Raccoon	0.005	0.007
Rabbit	0.023	0.034
Deer	0.003	0.007
Bobcat	0.008	0
Opossum	0.005	0.002
Squirrel	0.003	0.002

[1/] A liquid made from fermented eggs (Bullard et al. 1978).

[2/] Number of plots sampled.

Cattle track densities were significantly associated with population densities ($r = 0.83$, $p < 0.05$). Data from February were not used in the analysis because cattle activity was confounded by use of supplemental winter pastures during this period. Cattle population density (C) in numbers of cows and calves per range unit can be estimated from percent track frequency (T) by the regression equation: $C = 9.05 + 3.49T$. The coefficient of determination was 69%.

Tracks for some species such as bobwhite, wild turkey, bobcat, coyote, white-tailed deer, raccoon, and opossum occurred infrequently, and densities were not different among units or seasons (Tables 2 and 3). Tracks of these species usually occurred on only 1 or 2 of the 500 stations during each sampling period. Tracks of foxes, armadillos, squirrels, and rabbits occurred more frequently. Average track densities for armadillos and rabbits were higher in October than in February (Table 2). Squirrel tracks were not detected in February but densities were higher in October than in May (Table 2). Tracks of foxes were not detected during February or May but were present during July and October.

Track densities of wild animals did not differ statistically among the 4 grazing units when data were averaged among seasons. Averages from 3 days during July were not significantly different among the 2 grazing units for armadillos ($p > 0.05$). Track densities for foxes and squirrels were each significantly higher in one grazing unit compared to the other ($P < 0.05$). Track densities of rabbits were significantly higher in the NE range unit compared to the NW unit, but at least 5 sampling days would have been needed to detect statistically significant differences at the 0.05 level (Table 3).

Approximately 150 man-hours were required for establishment of all 500 stations. About 10 hours were required to prepare 100 stations for sampling tracks and about 7 hours to record data the following day. The 200 station unit required about 14 hours for preparation and about 8 hours for recording data. More time was needed during July (≈ 12 hrs. for 100 and 16 hrs. for 200 stations) because of high temperatures and humidity which required workers to rest more often, but daylight was sufficient to allow preparation of 200 stations during 1 day.

DISCUSSION

Armadillos, rabbits, and squirrels may be considered exclusive residents because their range is much smaller than the areas contained in each grazing unit. Foxes, deer, bobcats, and coyotes generally range over larger areas and because their tracks were infrequent, we regarded these species as transient residents on the grazing units.

Table 2. Mean (± SE) track densities for wild animals on the Palustris Experimental Forest, 1982.

	Sampling Period			
Species	February	May	July	October
Armadillo	.019 ± .013	.080 ± .023	.067 ± .010	.105 ± .034
Rabbit	.015 ± .008	.037 ± .009	.028 ± .011	.050 ± .019
White-tailed deer	.001 ± .001	.008 ± .005	.017 ± .010	.003 ± .003
Squirrel	0	.005 ± .003	.017 ± .008	.022 ± .012
Raccoon	.001 ± .001	.012 ± .008	0	.009 ± .012
Opossum	0	.005 ± .003	0	.003 ± .003
Bobcat	0	.009 ± .005	.011 ± .006	.003 ± .003
Fox	0	0	.023 ± .017	.028 ± .005
Coyote	0	0	.004 ± .002	.003 ± .003
Bobwhite	0	0	.002 ± .002	0
Wild turkey	0	0	.001 ± .001	0

Table 3. Mean (± SE) track densities for animals on 2 range units of the Palustris Experimental Forest sampled 3 consecutive days during July 1982.

	Track Density	
Species	NW Range Unit	NE Range Unit
Cattle[1]	0.116 ± 0.013	0
Armadillo	0.068 ± 0.034	0.061 ± 0.021
Rabbit[2]	0.029 ± 0.016	0.056 ± 0.019
Bobcat	0	0.025 ± 0.017
Fox[3]	0.004 ± 0.004	0.075 ± 0.032
Squirrel[3]	0.029 ± 0.019	0.006 ± 0.006
Coyote	0.004 ± 0.004	0.006 ± 0.006
Bobwhite	0.007 ± 0.007	0
Deer	0.018 ± 0.007	0.006 ± 0.006
Wild Turkey	0.004 ± 0.004	0

[1] Cattle not present in NE unit during sampling period.

[2] Significantly different at the 0.10 level.

[3] Significantly different at the 0.05 level.

Use of Scent

Although scent is intended for increasing the occurrence of predator tracks, our data suggest that fermented egg scent has no significant influence on the proportion of stations that might contain tracks of herbivorous or omnivorous wildlife. Because of the extra effort required, use of fermented egg scent is not warranted. On the other hand, other scents may have been more effective, especially for predators.

Interpretation of Data

Track densities represent relative changes in animal populations or activity within an area of measurement. For instance, the October rabbit track densities (0.050) increased more than 300% compared to February (0.015). This increase may represent increases in rabbit populations, increase in rabbit activity within the units or a combination of both. Increases in track density from winter to fall were about 400% and 500% for squirrels and armadillos, respectively. Activities of many animals differ among seasons and are probably affected by habitat quality. Therefore, care must be taken to minimize these sources of variation in any sampling scheme. On the other hand, these sources of variation are probably no greater for cross-country sampling than for road sampling. Unfortunately, there is no practical way to conduct track station studies over large blocks of land with known populations of wildlife. However, the significant relationship of track densities with known cattle densities, and the expected spring to fall increases in rabbit, squirrel, and armadillo track densities support the contention that cross-country track stations can provide an index to changes in population densities.

Because of the flat topography and forest range management, habitat on the 4 grazing units was more homogeneous and more similar than would be found in most forests. It is reasonable to presume that wildlife population densities would also be more similar among the 4 grazing units than among land units with greater differences. The detection of differences in rabbit and squirrel track densities between the 2 grazing units sampled for 3 consecutive days supports the contention that cross-country track stations can provide a reasonably sensitive index of population density changes and differences among areas, especially for comparison of very different habitats or land management practices.

Sampling Season and Intensity

The fact that track densities were highest during October corresponds to the assumption that population densities of wildlife are generally highest following the spring-summer reproductive season. The data may also reflect changes in movements; but the rabbit track density reasonably reflected the expected population increase. Increases for armadillos and squirrels also appeared biologically reasonable. Sampling during fall in the southeastern United States provides the highest track densities and the best opportunity for comparing densities among different wildlife populations or monitoring annual changes in game populations.

For armadillo, rabbit, and squirrel, track densities varied among seasons by 58%, 32%, and 72%, respectively for the unit (SE) with 200 sampling stations. For the 3 units with 100 stations each, average variation was 75%, 94%, and 98%, respectively. In addition, track densities for the 3 resident species generally increased from spring to fall for the SE unit but trends were more variable for the other 3 units (Table 4). Although not conclusive, these data suggest that higher sampling intensities provide more reliable indices of population changes. However, when 100 of the 200 stations from the SE unit were selected at random, track densities for the 3 species were not significantly different from track densities determined using all 200 stations according to chi-square analyses. Further study is required to determine whether the higher density of stations exposes more of the animals to sampling and provides a better index of population density. If this hypothesis is correct, then fewer sampling days would be required to obtain data for statistically evaluating population differences between sampling units compared to using a lower density of stations.

Table 4. Track densities for resident wildlife on range units of the Palustris Experimental Forest, 1982.

		Range Unit			
Species	Sample period	NE (100)[1/]	NW (100)	SW (100)	SE (200)
Armadillo	Feb	0	.020	0	.055
	May	.022	.079	.134	.085
	Jul	.061	.068	.045	.095
	Oct	.052	.100	.067	.202
Rabbit	Feb	.030	0	0	.030
	May	.022	.045	.061	.021
	Jul	.056	.029	0	.027
	Oct	.104	.033	.015	.047
Squirrel	Feb	0	0	0	0
	May	0	.011	0	.007
	Jul	.006	.029	0	.034
	Oct	.039	0	0	.047

[1/] Number of plots sampled.

We suggest sampling for about 5 days during any period in order to obtain replicates for statistical comparisons of treatments. Two hundred track stations per section are recommended for describing changes in population densities. However, 100 stations will provide a reasonable index although data may be less precise.

Predators and other transient wildlife must be sampled over much larger areas than are required for smaller less mobile species. We have performed cross-country track station sampling for deer studies on two 1000 ha areas of mixed loblolly pine-hardwood in southcentral Louisiana. Deer track frequencies were about

% and 27% in October for the 2 areas, spectively (unpublished data). Comparison of ese data with the low track frequencies for er on the Palustris Experimental Forest ggests that the size of area needed to conduct study with track stations is related to the ze of the population it supports as well as e species. In addition, deer density on the uthcentral Louisiana area with the lower track equency was estimated to be about 1 per 11 ha habitat while deer density on the area with e higher track frequency was estimated to be out 1 per 9 ha of habitat. These data further pport the contention that cross-country track ations can be used to detect differences in ldlife population densities.

SUMMARY

Cross-country deployment of track stations ovides a reasonable method for indexing opulations of wildlife. Population lationships can be indexed regardless of the istribution of roads. In comparison to ampling along roads, cross-country data epresent populations inhabiting all portions of n area. Sampling along roads probably provides dequate representation of wildlife inhabiting estern rangelands; however, topography in the outhern United States results in most roads eing constructed on ridges. Roads do not often llow unbiased, adequate sampling in ottomlands. In addition, vegetation associated ith roadsides is often different from that hich generally covers a forested area, so data ollected along roads may be biased and lead to rroneous indicators of actual population hanges. The cross-country method combines easonable theoretical rationale with practical onstraints of sampling.

Outside of cattle, there is no basis to ompare tracks of animals with known opulations. Consequently, only relative hanges in population or changes in activity evels are possible from these data. However, he data (1) establishes that there are certain pecies of wildlife on the area, (2) show that he presence of these species vary, and (3) ndicate that over time, certain species luctuate in number or activity level. The ross-country track station sampling system has he advantages of being easy to employ with ittle effort and it is easy to understand.

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Soils of Study Area in Harrison and Stone Counties, Mississippi

Rex E. Davis

Abstract.--The soils of the study area developed in the Citronelle, Graham Ferry, and Pascagoula formations of the lower coastal plain. These soils include Ultisols, Inceptisols, Entisols, Histosols, and Alfisols. Natural fertility is relatively low in most of the soils because of high rainfall, temperature, and the nature of the parent material. Soil drainage ranges from excessive to very poor depending mainly on topographic position.

This is an attempt to give an analysis of soils and landscapes in the designated study area for the Southern Evaluation Workshop. It is designed to give a baseline environmental setting upon which vegetation can be superimposed.

STUDY AREA

The study area consists of all or portions of sections 21, 22, 23, 24, T4S, R11W, and sections 19, 20, 21, 22, and 23, T4S, R10W in Stone County. In Harrison County all or portions of sections 25, 26, and 28, T4S, R11W and sections 26, 27, 28, 29, 30, 31, 32, 33, 34, T4N, R10W and sections 3, 4, and 5, T5N, R10W were studied. The area is in the Saucier Creek, Tuxachaney Creek, and Big Foot Creek drainage areas.

Elevation of the area ranges from 80 to just over 200 feet above mean sea level. The landscape consists of poorly drained nearly level flats to rolling and steep hillsides and gently sloping ridgetops. Floodplains range in width up to 1,500 feet and are dominated by poorly drained soils. Excessively drained natural levees occur along larger streams that have well defined channels.

In higher elevations of interfluvial areas soils are developed in the Citronelle formation. The Citronelle formation is a terrace deposit believed to be of fluvial origin.[1] These soils are dominated by loamy sand, sandy loam, and loam. Some of the loamy sands are believed to be eolian sands caused by "blow-outs".

The soils are McLaurin, Lucy, Poarch, and Eustis. Permeability ranges from moderate to rapid causing these soils to be drier than those of lower elevations. Soils that developed within the Citronelle formation are well drained or excessively drained. Vegetation is characterized by Longleaf pine, Huckleberry, and Yaupon.

The Graham Ferry formation is located below the Citronelle and above the Pascagoula formation and is considered to be deltaic in origin consisting of both fluvial and marine or brackish deposits.[1]

The Pascagoula formation outcrops at lower elevations. It is dominated by clays of deltaic or estaurine origin.[1]

The soils formed in the Graham Ferry and Pascagoula formations are generally poorly drained through moderately well drained and have clayey or fine loamy subsoils. Landscapes are most nearly level to rolling. Many wet weather seeps occur along the contact between the Citronelle formation and the material below.

CLIMATE

The climate is subtropical with warm summers and alternately warm and cold winters. The average daily maximum temperature is 58 degrees F. The average highest annual temperature is 98 degrees F and the average lowest annual temperature is 20 degrees F.

The average annual precipitation is 62.3 inches most of which falls during the summer months.[2]

1/ Brown, Glen Francis; Foster, Velora Meek; Adams, Robert Wynn [and others]. In: Geology and Ground-Water Resources of the Coastal Area in Mississippi; Mississippi State Geological Survey; 1944: 32-66.

2/ U.S. Department of Agriculture, Soil Conservation Service. In: Soil Survey of Harrison County Mississippi, 1975. 73-77.

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VEGETATION

Vegetation is an important tool in making soil surveys. One generally recognizes certain species as good soil indicator plants. Soil drainage, texture, parent material, and degree of erosion are important soil factors that relate to plant communities. Titi, pitcher plants, swamp bay, and many rushes and sedges are good indicators of poorly drained soils. Wax myrtle and certain galberries are good indicators of somewhat poorly and moderately well drained soils. Yaupon, dogwood, and huckleberry are good indicators of well drained soils. Sawtooth palmetto, bluejack oak, and turkey oak are good indicators of excessively drained soils. Some of these plants will occur on adjacent drainage classes but their abundance determines whether or not they are good indicators.

METHODS AND PROCEDURES

The procedures for making this soil survey are the same used for the National Cooperative Soil Survey. Location and intensity of the field observations were dictated by the position on the landscape and parent material. Observations were made by hand auger and hydraulic probe to the depth of 5 feet (1.5m) in normal mapping. Typical pedons were described for each map unit. Additional pedons were described to support the typical pedons.

The Harrison County part of the study area is part of the Harrison County, Mississippi, Soil Survey. The Stone County part was contracted to the Soil Conservation Service by the Forest Service in 1979. Later this was incorporated into the Stone County, Mississippi, Soil Survey.[3]

RESULTS AND DISCUSSION

Soils of the Area

The soils of the study area developed in coastal plain sediments that are low in inherent fertility. Most of them have a low cation exchange capacity and low base saturation level. Exceptions are soils of the Susquehanna series, which are Alfisols, and flood plain soils that have a high level of organic matter. The drainage class and topographic position of each soil series follows:

SERIES	DRAINAGE CLASS	TOPOGRAPHIC POSITION
Atmore	poor	upland depressions
Escambia	somewhat poor	stream terraces
Eustis	somewhat excessive	upland
Harleston	moderately well	upland and terrace
Jena	well	natural levee
Lucy	well	upland
Malbis	well or moderately well	upland
McLaurin	well	upland
Nahunta	somewhat poor	flood plain
Nugent	excessive	natural levee
Poarch	well or moderately well	upland
Ponzer	very poor	flood plain
Saucier	moderately well	upland
Smithton	poor	flood plain
Susquehanna	somewhat poor	upland

Classification of the soils in the study area is listed below.[4]

Atmore	Plinthic Paleaquult, coarse loamy siliceous thermic
Escambia	Plinthaquic Paleudult, coarse loamy siliceous thermic
Eustis	Psammentic Paleudult, sandy siliceous thermic
Harleston	Aquic Paleudult, coarse loamy siliceous thermic
Jena	Fluventic Dystrochrept, coarse loamy siliceous thermic
Lucy	Arenic Paleudult, loamy siliceous thermic

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[3] U.S. Department of Agriculture, Soil Conservation Service. Soil Survey of Designated Portion of Desoto National Forest in Stone County, Mississippi. [Unpublished report]. 1979.

[4] U.S. Department of Agriculture. Soil Taxonomy: A Basic System of Soil Classification for Making and Interpreting Soil Surveys. Soil Conservation Service, U.S.D.A. Handbook 436, 754pp., illus.

lbis	Plinthic Paleudult, fine loamy siliceous thermic
cLaurin	Typic Paleudult, coarse loamy siliceous thermic
hunta	Aeric Paleaquult, fine silty siliceous thermic
gent	Typic Udifluvent, sandy siliceous thermic
arch	Plinthic Paleudult, coarse loamy siliceous thermic
nzer	Terric Medisaprist, loamy mixed dysic thermic
ucier	Plinthaquic Paleudult, fine loamy siliceous thermic
ithton	Typic Paleudult, coarse loamy siliceous thermic
squehanna	Vertic Paleudalf, fine montmorillonitic thermic

Vegetation in the Longleaf-Slash Pine Forest, Biloxi District, Desoto National Forest, Mississippi

Aberdeen W. Stewart and George A. Hurst

Abstract.--Vegetation was studied on 4 areas on the Biloxi District, Desoto National Forest, Mississippi. Percent plant occupancy on line transects ranged from 53-73% and averaged 61.7%. A total of 153 species of plants was found. Basal area averaged 72 ft^2/ac, pine (Pinus spp.) height averaged 71 ft, pine age averaged 45 yrs, canopy cover averaged 23%, and number of stems averaged 592/ac. Of 44 tall brush (≦ 1 in. DBH, > 5 ft) species, Ilex coriacea and I. vomitoria were the most numerous. Low brush (< 5 ft) species numbered 84. Estimated current annual growth (dry weight) of low brush averaged 147 lb/ac and Ilex glabra, I. vomitoria, I. coriacea, Cornus florida, and Vaccinium elliottii were the most prominant species. Forage species numbered 103 and forage [grass, forbs, legumes, vines, and woody (up to 5 ft)] averaged 755 lb/ac in July, 1979 and 305 lb/ac in January, 1980. Less than 12% of the variation in forage and low brush weights was explained by overstory conditions. Forage weight was inversely related to percent canopy cover and low brush weight.

INTRODUCTION

The Longleaf (Pinus palustris) - slash pine (P. elliottii) forest type forms the western part of the longleaf pine belt and comprises about 5 million ac. This forest has produced good forage and timber simultaneously.

Mississippi State University, other institutions, the Soil Conservation Service, and the U. S. Forest Service conducted the Southern Evaluation Project (SEP) to study livestock, wildlife, forage, and timber relationships in the southern forest, and the impacts of these resources on recreation and watershed. The ultimate goal of SEP is to promote sound multiple-use management of southern forested public lands.

Vegetative and soil components of an area provide the basis on which much of management must depend. This study involved a vegetation survey and objectives were to (1) describe quantitatively and to determine differences among vegetation on 4 selected units in the SEP, Desoto National Forest and (2) evaluate relationships among parameters such as overstory, tall brush, low brush, and white-tailed deer (Odocoileus virginianus) forage.

STUDY AREA

Four areas in Harrison and Stone counties, Mississippi, on the Biloxi District, Desoto National Forest were selected and fenced by the Forest Service. The areas were in the rolling uplands of the Southern Lower Coastal Plain. Common soils series included Atmore, Bibb, Escambia, Eustis, Lucy, Malbis, Poarch, Saucier, and Smithton. Textures are generally well-drained, loamy sands to fine, sandy loams.

Normal annual rainfall for the general area is 57 in. and the average annual temperature is 66°F. A mild climate persists with the frost-free season being 259 days.

Forest stands were mostly natural, open-grown stands of longleaf and slash pine with the exception of several plantings of slash pine. A detailed description of the forest can be found in Stewart (1981). The Forest Service has used late winter controlled burning, on a 3-year rotation, as a general practice for many years. Cattle grazed most of the area prior to 1979.

The 4 areas (range units) varied from 2735 ac to 4135 ac and were located in Airey and Big Foot Allotments. Area 1 (2735 ac) was located in Forest Service compartment numbers 592, 593,

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594, and 595. Area 2 (3620 ac) was in compartments 574, 575, 617, and Area 3 (3396 ac) was located in compartments 570, 571, 572, 573, and 616. Area four (4135 ac) was located in compartments 566, 567, 568, and 569.

METHODS

In each of the 4 areas, 4 lines, 2640 ft long, were randomly established. Along each line, 9 systematically established, 330 ft apart, permanent sample points were located for a total of 144 sample points.

Line Transects

Species composition, frequency of occurrence, and percent occupancy were obtained by the line-intercept method (Canfield 1941). Transect lines were established in July, 1979 on sampling points 4 and 8 of each line for a total of 32 transects. A transect was 20 ft long and was bisected by the sample point center. The tape, divided into 0.1 ft intervals, was stretched 2 ft above ground at a 90-degree angle to the main line direction. Plants that occurred directly under the tape were identified and their linear occupancy was recorded. Species were grouped into plant categories: grass, forb, vine, shrub, tree, sedge, rush, and fern. Bare ground and debris were also recorded. Percent occupancy was the percentage of the total line occupied by a category. Frequency of occurrence was the number of times a plant category occurred.

Overstory

Overstory tree data were obtained in July, 1979, from 144 sample points. Stand data at each sample point was recorded as (1) nonstocked or regeneration, pines up to and including 3 yrs old, (2) saplings, pines more than 3 yrs old to 4 in. DBH, (3) poles, pines 4 to 9 in. DBH, or (4) sawtimber, pines more than 9 in. DBH.

From the sample point, pine and hardwood trees were measured for (1) basal area using a 10 factor prism, (2) DBH of prism-recorded trees with a DBH tape, (3) height of 1 dominant or codominant tree with a clinometer, and (4) tree age of 1 dominant or codominant tree from increment bores. Percent canopy cover was estimated.

Number of snags, dead trees at least 3.6 in. DBH, within a 33 ft radius of the sample point were recorded. Numbers of individual tree species within a 33 ft radius were also recorded.

Tall Brush

Tree, shrub, and vine data were obtained near peak biomass in July 1979. On milacre plots located at the sample point, percent canopy cover and canopy height in ft (to top of crown) for each species were estimated for trees, shrubs, and vines with stems 1 in. or less DBH and heights greater than 5 ft. Numbers of individuals by species were counted.

Low Brush

Low brush (browse) data were obtained in July of 1979 and 1980. On milacre plots located at the sample point, total current year's growth of trees, shrubs, and vines within 5 ft of the ground was estimated. Percent foliage ground cover was estimated. Browse species were estimated as greater or less than 10% of total composition. Degree of browsing on woody species was recorded in 5 categories (1-5); none; very light, difficult to find browsed plants on plot, less than 10%; light, infrequently find browsing on the plot, generally 10-35%; moderate, frequent evidence of browsing, generally 35-70%; heavy, extensive evidence of browsing, generally more than 70% of the plants browsed.

Forage

Forage (grasses, grasslikes, forbs, and browse) data were obtained in July of 1979 and near minimal biomass in January, 1980, using the ranked-set sampling technique (Halls and Dell 1966). One cluster of 3 circular plots (hoops) 42 in. in diameter (9.62 ft^2) were placed at arms length near each sample point, 1 plot to the left, 1 plot to the right, and 1 plot directly in front of the observer. High, medium, and low ranks were assigned to the hoops for each sample according to an occular estimation of forage dry weight (current annual growth) in each plot. High, medium, and low plots were sampled in succession until 3 plots of each category were obtained for a total of 9 sample points per line. Forage weight was estimated within each plot to a height of 5 ft from ground level.

During July, 1980 forage species were estimated as a percentage based on dry weight. Degree of grazing was recorded as in 1979, as well as percent of basal herbaceous ground cover, foliage ground cover, leaf litter cover, bare ground cover, and rock cover were estimated.

Soils

Soil data were obtained in July, 1980 by Rex E. Davis of the USDA, SCS, Hattiesburg, MS. Soil samples were taken near the sample point using a tubular bucket type soil auger. Soil types consisting of series and texture were identified for each sample point.

Statistical Analysis

Statistical analyses were conducted by Dr. Walter J. Drapala, Dept. of Experimental Statistics, Miss. Agric. and Forestry Experiment Station, Mississippi State Univ. Analysis of variance and multiple regression programs were used to analyze overstory, low brush, and forage data. Duncan's New Multiple Range Test was used to test for differences among means.

RESULTS

Species Composition

A total of 153 plant species was found on transects on the 4 areas. There were 74 species of forbs (48%), 23 grasses, 19 shrubs, 11 vines, 11 trees, 9 sedges, 4 rushes, and 2 ferns. A2 (85) and A3 (87) contained the greater numbers of species while A1 (55) and A4 (58) had fewer species.

Line Transects

Total plant occupancy vaired from 53 (A4) to 73% (A2), and averaged 61.7%. Debris, shrubs, and grasses had the highest occupancy percentages (Table 1).

Overstory

Basal area for A1-4 (nsd, $P > 0.05$) averaged 72 ft^2/ac (Table 2). Basal area ranged from 29 ft^2/ac on A2, line 3, to 127 ft^2/ac on A4, line 3. Trees tallied for basal area averaged 66% pine. Pine tree height on A 1-4 (significantly lower on A2 ($P < 0.05$) averaged 71 ft. Hardwood tree height averaged 57 ft. Pine tree age for A1-4 averaged 45 yrs and was significantly lower on A2 because of several young plantations being present. Hardwood age averaged 49 yrs. Canopy cover averaged 23% and was lowest (11%) on A2.

Number of stems (nsd, $P > 0.05$) averaged 592/ac, and ranged from 146/ac (A4, line 1) to 1,086/ac (A2, line 2).

A total of 49 overstory species was recorded and the major species, based on percent of stems were *Pinus elliottii* (13.6), *P. palustris* (12.1), *Ilex vomitoria* (11.3), *Cliftonia monophylla* (9.3), *Cornus florida* (7.1), *Cyrilla racemiflora* (6.4), *Magnolia virginiana* (5.8), *Ilex coriacea* (5.2), *Myrica cerifera* (4.9), and *Nyssa sylvatica* (4.2).

Number of snags averaged 10/ac and ranged from 0 (A1, lines 1 and 2) to 33/ac (A3, line 3).

Table 1.--Average plant frequency, occupancy, and percent occupancy by category on line transects in longleaf - slash pine forests, Desoto National Forest, July 1979

Plant category	Freq. 1/	Occ. 2/	%Occ. 3/
Grass	17.8	3.8	19.1
Forb	11.0	1.8	8.8
Vine	5.2	1.0	4.8
Shrub	16.5	4.6	22.7
Tree	3.2	0.8	4.3
Sedge	1.4	0.2	1.1
Rush	0.2	0.1	0.1
Fern	0.1	0.1	0.1
Unknown	0.5	0.3	1.3
Total			61.7
Bare ground	0.3	0.2	0.9
Debris	15.7	7.7	38.5

1/Frequency = number of times a plant category occurred.

2/Occupancy = length (ft) of line transect occupied by a plant category.

3/Percent occupancy = % of line transect occupied by a plant category.

Table 2.--Averages of overstory tree measurements by study area and line, Desoto National Forest, Stone and Harrison Counties, MS, July 1979

Study area	Line	Basal area		Height (ft)		Age (yrs)		Canopy cover (%)	No. Stems/ac	No. Snags/ac
		ft^2/ac	% pine	Pine	Hdwood	Pine	Hdwood			
1	1	74	57	71	44	45	26	29	862	0
	2	49	61	49	42	23	60	8	627	0
	3	50	64	75	65	51	60	17	287	7
	4	49	82	82	--	52	--	13	544	6
	Mean	56a[1]	66	69a	50	43ab	48	17ab	580a	3
2	1	72	85	66	--	40	--	16	444	18
	2	93	40	57	46	30	46	18	1086	13
	3	29	77	62	--	55	--	3	436	0
	4	36	94	38	--	22	--	8	651	3
	Mean	58a	74	56b	46	37a	46	11a	654a	9
3	1	109	55	84	--	64	--	33	866	16
	2	86	55	73	--	40	--	31	914	14
	3	83	40	74	--	39	--	30	712	17
	4	71	67	71	56	47	43	17	313	3
	Mean	87a	54	76a	56	47b	43	28bc	701a	13
4	1	71	97	85	74	56	57	35	146	7
	2	83	54	82	--	53	--	33	224	4
	3	127	56	92	--	58	--	41	696	33
	4	71	64	71	--	41	--	27	670	21
	Mean	88a	68	82a	74	52b	57	34c	434a	16
Total Mean		72	66	71	57	45	49	23	592	10

[1] Means for basal area, pine height, pine age, canopy cover, and number of stems significantly different, $P > 0.05$, if not followed by the same small letter.

Tall Brush and Vines

Tall brush and vines ($\leq$ 1 in. dbh, $>$5 ft high) species numbered 44. Areas 1 and 2 contained 26 and 28 species, while A3 and A4 contained 19 and 16 species, respectively.

Canopy height for the 4 areas averaged 8.4 ft and ranged from 6 to 20 ft. Predominant species were *Cephalanthus occidentalis*, *Gelsemium sempervirens*, *Ilex vomitoria*, *Liriodendron tulipifera*, *Quercus incana*, *Rhus radicans*, *Smilax glauca*, *S. laurifolia*, *S. rotundifolia*, *Vaccinium arboreum*, and *Vitis rotundifolia*.

Percent ground cover, based on canopy cover at ground level, averaged 6.48 for the 4 areas. *Cliftonia momophylla* (1.03%), *Ilex coriacea* (1.63%), and *I. vomitoria* (1.08%) had the highest ground cover.

Number of stems averaged 634/ac and most prevalent species were *Acer rubrum* (20/ac), *Cliftonia monophylla* (62/ac), *Cornus florida* (22/ac), *Ilex coriacea* (263/ac), *I. vomitoria* (91/ac), *Magnolia virginiana* (18/ac), and *Symplocos tinctoria* (20/ac). Area 1 averaged 695, A2 531, A3 625, and A4 665/ac.

Low Brush

Low brush ($\leq$ 5 ft high) species averaged 80 (July 1979) and 84 (July 1980) on the 4 areas. *Ilex glabra*, *I. vomitoria*, *I. coriacea*, *Cornus florida*, and *Vaccinium elliottii* were the most prominant species. Average estimated low brush weight (July 1979 and 1980) on the 4 areas was 147 lbs/ac (Table 3).

Low brush weights were significantly greater ($P < 0.05$) on A1 for 1979, but there was nsd ($P > 0.05$) among areas for 1980.

Degree of browsing was between none and light for the 4 areas, ranging from 1.22 to 2.33. Assuming desirable deer browse weight was a maximum of 80% of total low brush weight, browse ranged from 101 to 147 lbs/ac and averaged 118 lb/ac in July 1979.

Table 3.--Average estimated low brush weight (lbs/ac), by study area and line, Desoto National Forest, Stone and Harrison Counties, MS, July 1979 and 1980

Area	Line	July 1979	July 1980	Mean
1	1	184	110	147
	2	150	115	133
	3	348	125	237
	4	201	235	218
	Mean	221a[1]	146c	184
2	1	90	136	113
	2	97	209	153
	3	100	111	106
	4	91	178	135
	Mean	94b	158c	126
3	1	119	174	147
	2	200	128	164
	3	99	173	136
	4	90	107	99
	Mean	127b	145c	136
4	1	92	138	115
	2	125	150	138
	3	60	204	132
	4	98	270	184
	Mean	94b	191c	143

[1] Means for July 1979 and then 1980 significantly different, $P < 0.05$, if not followed by the same small letter.

Forage

Forage species (grass, forb, legume, vine, and woody ≤ 5 ft high) numbered 103 on the 4 areas. Area 4 contained the greatest number of species (63) followed by A3 with 53, and A1 and 2 had 51 each. Average estimated forage weight for July, 1979 was 755 lbs/ac (Table 4), and was 305 lbs/ac in January, 1980. Only those portions of the current annual growth which were considered palatable (selected forage) to deer or cattle were estimated. The wood category averaged 71% of the total estimated forage weight in July, 1980 (Table 5).

Table 4.--Average estimated forage weight (lbs/ac) by study area and line, Desoto National Forest, Stone and Harrison Counties, MS, July 1979 and January 1980

Area	Line	July 1979	January 1980
1	1	292	238
	2	763	134
	3	834	115
	4	983	257
	Mean	696a[1]	191
2	1	752	---
	2	736	367
	3	675	305
	4	1261	276
	Mean	856a	306
3	1	782	479
	2	766	577
	3	961	314
	4	566	161
	Mean	769a	317
4	1	537	271
	2	701	burned
	3	1037	512
	4	505	519
	Mean	695a	406

[1] Means for July 1979 significantly different $P \leq 0.05$, if not followed by the same small letter.

Table 5.--Average percent of estimated weight (July 1980) and estimated forage weight (July 1979) by plant category, Desoto National Forest, and Harrison Counties, MS

Plant category	% of Weight	lbs/ac
Grass	7.71[1]	58[2]
Forb	8.38	66
Legume	1.15	9
Vine	11.35	85
Woody	71.38	537
Total	100.00	755

[1] Based on estimated weight, 9.6 ft^2 plots, July 1980.

[2] Based on percent of July, 1980, estimated weight.

Basal herbaceous ground cover was greatest (0.95%) for A4 (Table 6). Foliage ground cover was between 23% on A3 and 30% on A2. Leaf litter cover was the greatest cover component, occupying 63% of A3 and A4, to 82% A2. Bare ground cover was more than twice as great on A3 (13%) as on any other area. Rock cover was negligible. Degree of grazing was none to light.

Table 6.--Average estimated basal herb cover, foliage ground cover, degree of grazing, leaf litter cover, bare ground cover, and rock cover by area, Desoto National Forest, Stone and Harrison Counties, MS, July 1979

	Area			
	1	2	3	4
Basal herb ground cover (%)	0.50	0.22	0.53	0.95
Foliage ground cover (%)	28.78	29.83	23.17	26.21
Degree of grazing (1-5)[1/]	1.31	1.57	1.47	1.13
Leaf litter cover (%)	80.36	82.36	62.81	63.22
Bare ground cover (%)	5.40	5.89	12.75	2.42
Rock cover (%)	0.03	0.00	0.03	0.00

[1/] 1 = none; 2 = very light; 3 = light; 4 = moderate; 5 = heavy.

Vegetative Relationships

Multiple regression analyses were performed on the overstory, low brush, and forage components of the study areas with a low measure of success probably due to the open nature of the longleaf - slash pine stands. Height and age were most closely related ($r^2 = .60$), followed by basal area and percent cover ($r^2 = .53$). Less than 12 percent of the variation in forage and low brush weights was explained by overstory conditions. Overstory components were lower on A1 and A2 because 14 and 17%, respectively, of the sampling points were in pine plantations younger than 37 years (Table 7). Forage weight showed a strong inverse relationship to percent canopy cover and, to a lesser degree, basal area. This trend was similar to the results of Halls and Schuster (1965), Wiggers et al. (1978), and Hurst et al. (1979). Low brush weight was positively related to percent canopy cover. Low brush and forage weights were inversely related due to a measure of overlap in space occupation.

Deer Browse

Assuming desirable browse weight was a maximum of 80% of total low brush weight, browse ranged from 101-147 lbs/ac, and averaged 118 lbs/ac. Much of the browse was Ilex which was found to be heavily used by deer in South Mississippi (Mitchell 1980).

Soils

Soils ranged from somewhat excessively drained to very poorly drained and 19 series were found on the 4 areas (Table 8).

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Table 7.--Average overstory, forage, and low brush measurements in pine plantations, Desoto National Forest, Stone and Harrison Counties, MS, July 1979

Plantation age (yrs)	Type[1]	Basal Area (ft^2/ac)	Height (ft)	Cover (%)	No. Stems (/ac)	Forage (lbs/ac)	Low Brush (lbs/ac)
≤ 3	SL	13	20	5	408	948	160
11-16	SL,LL	40	31	13	832	715	132
19-25	SL	53	32	9	628	1324	169
37	LL	40	64	2	624	650	191

[1] SL = slash pine; LL = longleaf pine.

Table 8.--Average percent soil series by study area, Desoto National Forest, Stone and Harrison Counties, MS, July 1980

		Area			
Series	Texture	1	2	3	4
Alaga	loamy sand	2.8	--	--	5.6
Atmore	find sandy loam	--	11.1	13.9	--
Bibb	silt loam	2.8	--	--	--
	sandy loam	2.8	--	--	2.8
	fine sandy loam	--	2.8	8.3	--
	loam	--	2.8	--	--
Borrow area		--	5.6	--	--
Escambia	fine sandy loam	--	13.9	11.1	11.1
	sandy loam	--	--	--	2.8
Eustis	loamy sand	19.4	--	--	--
Harleston	fine sandy loam	--	2.8	2.8	--
Johnston	muck	--	--	2.8	--
Lucy	loamy sand	11.1	--	8.3	--
Malbis	fine sandy loam	11.1	5.6	8.3	2.8
McLaurin	fine sandy loam	5.6	--	--	--
	loamy sand	2.8	--	2.8	--
Plummer	loamy sand	--	--	--	2.8
Poarch	loamy sand	5.6	--	--	2.8
	fine sandy loam	11.1	16.7	2.8	33.3
Ruston	fine sandy loam	2.8	--	--	--
	loamy sand	--	--	--	2.8
Saucier	loamy sand	2.8	--	--	--
	fine sandy loam	5.6	19.4	2.8	8.3
Smithton	fine sandy loam	--	13.9	33.3	25.0
Susquehannah	silt loam	2.8	--	2.8	--
	fine sandy loam	--	5.6	--	--
Troup	loamy sand	8.3	--	--	--
Wagram	loamy sand	2.8	--	--	--

Amphibians and Reptiles on Longleaf-Slash Pine Forests in Southern Mississippi

Henry A. Pearson, Renne R. Lohoefener, and James L. Wolfe

Abstract.--Amphibians and reptiles were sampled during 1980-1982 on more than 20 square miles of the Biloxi Ranger District, DeSoto National Forest, in Southern Mississippi. Five stand classes or habitats (regeneration, saplings, poles, sawtimber, and bayheads) were sampled within each of four management units. The diverse fauna were measured by several survey methods, including active searches--both diurnal and nocturnal, permanent line transects, anuran calls after or during rainfall, pit-fall traps, and funnel trap stations.

Highest numbers of salamander species and individuals were recorded on bayheads. Toad and frog species diversities were similar among all stand types, but numbers of individuals were higher on bayheads. Species diversities of turtles and lizards were also similar across stand types; highest individual counts of lizards occurred in poletimber stands, but relatively high counts occurred in all stands. Snake species diversity, individuals, and frequency were lowest on regeneration areas.

INTRODUCTION

The longleaf-slash pine forest association covers more than 17 million acres of the lower Gulf Coastal Plain from Texas to Florida (Shiflet 1980). It is important for commercial timber and livestock production and is a unique biological community. In Mississippi, this forest association makes up 1.3 million acres and is the predominant forest type of the Pine Hills and Lower Coastal Plain physiographical provinces (Lowe 1921, Cross et al. 1974, Lohoefener and Altig 1983).

This herpetological study for the Southern Evaluation Project, Biloxi Ranger District, DeSoto National Forest-Mississippi, was conducted during 1980, 1981, and 1982 (Wolfe and Lohoefener 1980, Lohoefener 1981, 1982b). The objective of this study was to describe the amphibian and reptile abundance and diversity within five forest stand classes in the longleaf-slash pine type study area in Mississippi. Forest stand classes (habitats) studied were regeneration (clear-cuts), saplings, poles, sawtimber, and bayheads (Wolfe and Lohoefener 1983).

STUDY AREA

The study area, subdivided into four management units, was located in northern Harrison and southern Stone counties, Mississippi (Wolfe and Lohoefener 1983). The topography consisted of gently rolling hills dissected by small streams (some intermittent) that were bordered by narrow zones of hardwoods (Wolfe and Lohoefener 1983). Longleaf pine (*Pinus palustris*) and slash pine (*P. elliottii*), occurring in various stages of succession from regeneration to mature trees, were the dominant overstory trees. The understory consisted of bluestem grasses (*Andropogon* spp., *Schizachyrium* spp.), panicums (*Panicum* spp., *Dicanthelium* spp.), wiregrass (*Aristida stricta*), yaupon (*Ilex vomitoria*), blackberries (*Rubus* spp.), gallberry (*Ilex glabra*, *I. coriacea*), and a variety of forbs and other plants (Stewart 1981). Control burning was routinely practiced at 3- to 5-year intervals.

METHODS AND PROCEDURES

In 1980, four forest stand classes or habitats (regeneration--pines 3 years old or younger, saplings--pines more than 3 years old and up to 4 in d.b.h.; poles--pines 4 to 9 in d.b.h., and sawtimber--pines more than 9 in d.b.h.) were studied in two management units. In 1981, studies were expanded to four management units and five habitats; bayheads (baygalls), mesic-hydric hardwood habitats were added. This created a total of 20 study areas.

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Several census methods were used. Because little of the habitat within the management units was suitable for salamanders, the 1980 surveys did not concentrate on salamanders, noting them only when found incidental to the surveys. The 1981 and 1982 surveys included all terrestrial herpetofauna in each of the five habitat types; aquatic amphibians were also censused in selected streams, and gopher tortoises were censused throughout the four management areas. Amphibians and reptiles were surveyed during 17 days (March-June) in 1980, 40 days (April-June) in 1981, and 48 days (March-September) in 1982.

Active Searches

Both diurnal and nocturnal searches were made along approximately 1300-ft-long permanent line transects bisecting each stand type (Wolfe and Lohoefener 1980, Lohoefener 1981, 1982b). Lizards were counted along each transect during late morning and late afternoon, while snakes were counted during the day and at night. Debris within 33 feet on either side of the transect line was searched. During nocturnal searches, a light with a red acetate cover was used so that the herpetofauna would not be alarmed.

Anuran Call Census

Anurans (toads and frogs) were surveyed by call counts from 7:30 p.m. to midnight after or during rainfall--when they are most active. However, dryness during spring of 1982 hampered these surveys. Portable equipment was used to record the more complex calling aggregations for later identification. Periodic stops were made along the transects and a 90° directional parabolic reflector was held in each of the four cardinal directions for 2 minutes while vocalizations were recorded.

Pit-fall Traps

Twenty-five gallon cans were buried flush with the soil surface in each of the forest stands. A total of 500 cans were buried for this study. The gallon can was found to be most useful with the ground skink (*Scincella lateralis*). These cans were replaced in 1982 with deeper cans (5-gallon buckets) to ensure that some herpetofauna did not escape.

Funnel Traps

One trap station with three funnel traps (Lohoefener 1981) was established in each stand. The traps were used in conjunction with two 50-ft long polyethelene fences placed at a 30° angle. A central trap was placed where the fences joined and one trap was placed at the outer end of each 50-ft fence. Traps were placed in shallow trenches so the protruding PVC pipe entrance was flush with the ground. In 1982, the trap stations were modified to include four 30-ft drift fences in a zigzag layout using both the pit-fall and funnel traps (Loehoefener 1982b).

Toads and Frogs

Anurans could not be censused uniformly because of the lack of precipitation; consequent the results are biased to sites with standing water, which was not uniform across study areas. Some anurans were added to the species lists by active search techniques, funnel traps, and--to less extent--the pitfall traps. Anuran call censuses were the most reliable technique.

Salamanders

Most salamanders were found by active searches. No salamanders were taken in the pitfall traps, but a few were taken in bayheads in funnel traps. Active search techniques are the most valuable for this component of the herpetofauna.

Turtles

All turtle data, except for one eastern box turtle (*Terrapene carolina*) and one stinkpot tur (*Sternotherus odoratus*), were the result of acti diurnal searches. The gopher tortoise (*Gopherus polyphemus*) is a herbivore that primarily feeds grasses. Due to the gopher tortoise's rarity an possible future endangered or threatened status, each management unit was searched for burrows of this species (Lohoefener 1982a). Gopher tortois burrows were counted only if active.

Lizards

Some species of lizards are common and readi observable. All the census methods described earlier were used in collecting lizards. The pitfall traps were most useful to capture the groun skink; however, the funnel traps were the most su cessful for all lizards.

Snakes

Early in spring, diurnal searches were most successful in censusing snakes. By mid-May, nocturnal searches and the use of the funnel traps replaced diurnal searches because the snakes soug shelter from the heat of day. The funnel traps were most useful for snakes, especially on the bayheads.

RESULTS AND DISCUSSION

Two classes of herpetofauna were found in th study area, each class including two orders (*Amphibia*: Caudata and Anura; *Reptilia*: Testudina and Squamata). Each of these were represented by several families and species.

Toads, frogs, and lizards occurred more frequently than salamanders, turtles, and snakes in the five stand types (table 1). Bayheads had a greater number of salamander species than the dri upland sites (table 2). A total of 61 herpetofaunal species were found on the area. The number of species was fairly similar among stand types, varying from a low of 33 species in the regeneration type to a high of 38 species in

Table 1.--Percent frequency of occurrence of amphibians and reptile species occurring in five habitats of a longleaf-slash pine forest in Mississippi 1/

	Regeneration	Saplings	Pole	Sawtimber	Bayheads	Average
Salamanders	0.5	0	1.5	2.0	8.8	2.6
Toads and Frogs	6.9	8.0	8.0	8.0	8.4	7.9
Turtles	1.3	2.5	0.6	2.5	2.3	1.8
Lizards	8.1	9.7	11.7	10.6	8.7	9.8
Snakes	2.3	2.7	3.7	2.8	3.3	3.0

1/ Percent frequency is the number of species encountered divided by the total number of locations.

Table 2.--Number of amphibian and reptile species occurring in five habitats of a longleaf-slash pine forest in Mississippi

	Regeneration	Saplings	Pole	Sawtimber	Bayheads	Total
Salamanders	1	0	2	1	5	5
Toads and Frogs	13	13	11	13	12	16
Turtles	2	2	1	1	3	4
Lizards	7	9	6	6	6	9
Snakes	10	14	15	15	12	27
Totals	33	38	35	36	38	61

bayhead and sapling type. Numbers of all herpetofauna were more abundant on pole sites than the other sites due to the high counts of lizards (table 3). Lizards were least abundant on bayheads; toads, frogs, and salamanders were most abundant on bayheads. Total numbers of species occurring on the four management units within the five habitats are recorded in table 3 from three study reports (Wolfe and Lohoefener 1980, Lohoefener 1981, 1982b).

Salamanders

Five species of salamanders were found (*Desmognathus auriculatus*, *Eurycea longicauda*, *Eurycea quadridigitatus*, *Plethodon glutinosus*, and *Notophthalmus viridescens louisianensis*). It is not surprising that most of the salamanders were found in the bayhead areas because of those areas' moist environment. In most instances, the other habitats were too sandy and dry and provided little cover for salamanders. Slimy salamanders (*P. glutinosus*) located in immature sawtimber were found in depressions with deciduous shrubbery and abundant leaf litter. Only one central newt (*N. v. louisianensis*) was found while searching for amphibians.

More species of salamanders may occur on the study area than were found, because the months of February and March are usually the best times to find salamanders and the 1981 surveys were not begun until April. Also, the spring of 1981 was unusually dry, and probably many species of salamanders did not emerge from the winter refuges.

Toads and Frogs

During the 1980 survey, March data were more valuable than June data in quantifying anurans. No new species were encountered in June and population levels were lower than in March. This was probably due to the dry weather depressing the vocalizations rather than an actual drop in individuals present.

Anurans must have water in their life-cycles. Ponds throughout these habitats usually contain water during the spring months. During the spring drought of 1981, however, little breeding of anurans took place except in the bayheads. Bayheads serve as reservoirs for anurans during these dry times and help to maintain populations that can expand in wetter years or seasons. The spring of 1982 was comparatively wet and produced the highest anuran counts.

Table 3.--Total numbers of amphibians and reptile counted, 1980-1982

Species	Regeneration	Sapling	Poletimber	Sawtimber	Bayheads
	#	#	#	#	#
Class Amphibia					
Order Caudata					
Family Plethodontidae					
Desmognathus auriculatus Southern dusky salamander					1
Eurycea longicauda Long-tailed salamander			1		8
Eurycea quadridigitatus Dwarf salamander					13
Plethodon glutinosus Slimy salamander	3		5	13	14
Family Salamandridae					
Notophthalmus viridescens Central newt					1
TOTAL SALAMANDERS (59)	3	0	6	13	37
Order Anura[1]					
Family Bufonidae					
Bufo terrestris Southern toad	23	9p[1]	9	21p	25pm[2]
Bufo woodhousei Common toad	6	6p	8p	3	4p
Family Hylidae					
Acris gryllus Southern cricket frog	5	2p	4	2p	36p
Hyla avivoca Bird voiced tree frog		p		1	
Hyla cinerea Green tree frog					4p
Hyla crucifer Peeper tree frog	8	2	2p	2p	28p
Hyla fermoralis Pine woods tree frog	2	p	1p	1p	1p
Hyla gratiosa Barking tree frog	1	p			4p
Hyla squirella Squirrel tree frog	1	p	1p	p	m
Hyla versicolor Gray tree frog	3	2	12p	3p	4p
Pseudacris nigrita Southern chorus frog	5	2	2	2	
Pseudacris triseriata Chorus frog				1	
Family Microhylidae					
Gastrophryne carolinensis Eastern narrow mouthed toad	7	4p	4p	5p	3p
Family Pelobatidae					
Scaphiopus holbrooki Eastern spadefoot toad	1				

Table 3.--(continued)

Species	Regeneration	Sapling	Poletimber	Sawtimber	Bayheads
	#	#	#	#	#
Family Ranidae					
Rana clamitans Green frog	2	4	2	1	7p
Rana sphenocephala Southern leopard frog	1	2	1p	1p	9pm
TOTAL TOADS AND FROGS (312 pm)	65	33p	46p	43p	125pm
Class Reptilia					
Order Testudinata					
Family Emydidae					
Terrapene carolina Eastern box turtle	1	2		5	1
Family Kinosternidae					
Kinosternon subrubrum Eastern mud turtle					1
Sternotherus odoratus Stinkpot turtle					1
Family Testudinidae					
Gopherus polyphemus Gopher tortoise	2	5	1		
TOTAL TURTLES (19)	3	7	1	5	3
Order Squamata					
Suborder Lacertilia					
Family Anguidae					
Ophisaurus ventralis Eastern glass lizard	1	1			
Family Iquanidae					
Anolis carolinensis Green anole	7	13m	51m	29m	24m
Sceloporus undulatus Fence lizard	28	28m	42	23m	24
Family Scincidae					
Eumeces anthracinus Coal skink		1			
Eumeces fasciatus Five-lined skink	4	1	6	2	18
Eumeces inexpectatus Southeastern skink	5	10	17	3	6
Eumeces laticeps Broad-headed skink	1	m	m	2	1
Scincella lateralis Ground skink	103	85m	139m	104m	61m

Table 3.--(continued)

Species	Regeneration	Sapling	Poletimber	Sawtimber	Bayheads
	#	#	#	#	#
Family Teidae					
Cnemidophorus sexlineatus Six-lined race runner		7			
TOTAL LIZARDS (847m)	149	146m	255m	163m	134m
Suborder Serpentes					
Family Colubridae					
Carphophis amoenus Worm snake				2	
Cemophora coccinea Scarlet snake	2	1	2	3	3
Coluber constrictor Black racer	11	20	16	11	13
Diadophis punctatus Ringneck snake			2	1	2
Elaphe guttata Corn snake					2
Elaphe obsoleta Rat snake	1	1	3	2	
Farancia abacura Mud snake					1
Heterodon platyrhinos Eastern hognose snake	2	1			
Heterodon simus Southern hognose snake			2		
Lampropeltis getulus Speckled king snake	4	2	5	4	6
Lampropeltis triangulum Scarlet kingsnake		2			
Masticophis flagellum Eastern coachwhip	1	1	2		
Nerodia fasciata Banded water snake					1
Opheodrys aestivus Rough green snake		1	2	2	4
Pituophis melanoleucus Black pine snake			1	1	
Regina rigida Glossy water snake		1			
Rhadineae flavilota Pine woods snake	1			4	
Storeria dekayi Brown snake		1		1	
Tantilla coronata Southeastern crowned snake		2	1		
Thamnophis sauritus Ribbon snake			1		2
Thamnophis sirtalis Eastern garter snake	1	2		1	2
Virginia valeriae Smooth earth snake			1	1	
Virginia striatula Rough earth snake	2	2	7	3	1

Table 3.--(continued)

Species	Regeneration	Sapling	Poletimber	Sawtimber	Bayheads
	#	#	#	#	#
Family Elapidae					
Micrurus fulvius Coral snake			1		
Family Viperidae					
Agkistrodon contortrix Southern copperhead				1	
Agkistrodon piscivorus Eastern cottonmouth			1		1m
Crotalus adamanteus Eastern diamondback	3	3	2	1	
TOTAL SNAKES (193m)	28	40	49	38	38m
GRAND TOTAL HERPETILES (1430 pm)	248	226pm	357pm	262pm	337pm

[1] p--refers to more than a few anurans present.

[2] m--refers to many individuals present.

The 16 species of anurans recorded during the study probably represent the species breeding at the time of study. Since the bayheads had some form of water present throughout the study period, a great diversity or number of anurans was expected in these areas. Similarly, it is not surprising that the upland areas had fewer numbers of anurans. The sapling, pole, and sawtimber areas seemed to have anurans directly proportional to the amount of cover and the amount and duration of water available. Areas that had a greater diversity of anurans also had more water and cover.

The southern toad (Bufo terrestris) and common toad (B. woodhousei fowleri) were found to be evenly distributed throughout the four range units, with the southern toad being most common. The southern toad was commonly found vocalizing near small puddles in the sandy soils. The eastern spadefoot toad (Scaphiopus holbrooki) was found only in regeneration areas while the eastern narrow-mouthed toad (Gastrophryne carolinensis) occurred in all the forest stand classes.

The green (Rana clamitans), southern leopard (R. sphenocephala), and southern cricket (Acris gryllus) frogs were found in all the forest stand classes. Also, several tree frogs--peeper (Hyla crucifer), pine woods (H. fermoralis), squirrel (H. squirella), and gray (H. versicolor)--were in all forest stands. The bird-voiced (H. avivoca), green (H. cinerea), and barking (H. gratiosa) tree frogs were found in some forest stands but not all; however, all were found in bayheads. The chorus frogs (Pseudacris nigrita and P. triseriata feriarum) were found only on the upland stands but not in bayheads.

Turtles

None of the water courses in the study areas was stable enough or of sufficient magnitude to support aquatic turtles. All turtles found were terrestrial (Terrapene, Gopherus) or semi-aquatic (Kinosternon, Sternotherus). The eastern boxturtle is fairly ubiquitous, and in this study, was found more or less uniformly throughout the stand types. The gopher tortoise was found in sapling, pole, and regeneration areas. All gopher tortoises were isolated individuals; usually healthy gopher tortoise populations occur in colonies (Lohoefener 1982a). However, the pole, regeneration, and one of the sapling areas formed a continuum in location. Isolated tortoises do not become part of the reproductive pool. Unless these tortoises disperse, the population will likely die out. The stinkpot turtle and eastern mud turtle (Kinosternon subrubrum) require water yearlong and were found only in the bayhead areas. They both may be more common in these habitats than the survey revealed.

Lizards

As indicated by the results of this study, the green anole (Anolis carolinensis), fence lizard (Sceloporus undulatus), and ground skink tolerate these habitats. The green anole prefers shaded areas (Behler and King 1979). Both the green anole and fence lizard increase as density of vegetation increases. The ground skink needs ground cover, such as leaf litter, to survive. Because of th ubiquitousness, the ease with which they were c tured in pit-fall and funnel traps, and the num in which they occur, the ground skink may be a lizard species for monitoring habitat changes.

The broad-headed skink (Eumeces laticeps); five-lined skink (E. fasciatus), both common in mesic areas, and southeastern skink (E. inexpectatus), common in xeric areas (Behler an King 1979), were found in the bayheads as well in all the upland forest stand classes. Coal skinks (E. anthracinus pluvialis) were found on in sapling stands. Most of the skinks were captured in the funnel traps.

The eastern glass lizard (Ophisaurus ventra lis) was probably more abundant than reflected this survey. It is secretive by nature and usua occurs in suitable ground cover and mesic conditions, but it was found only in regeneration a sapling stands. The six-lined racerunner (Cnemidophorus sexlineatus) prefers dry, sunny, open woodlands on well-drained soils (Behler an King 1979) and was found only in sapling stands.

Snakes

The black racer (Coluber constrictor priapu was the most commonly observed snake in this stu It occupies a wide range of habitats and is both diurnal and nocturnal. Its habit of sunning mak it easy to locate (or observe). The racer was found in 14 of the 20 study areas in all forest stand classes and probably occurred in all 20. speckled kingsnake (Lampropeltis getulus holbrooki), also found in all forest stand class was common, being found in 6 of the 20 areas. I large, slow movement, and diurnal activity make readily observable. The scarlet kingsnake (L. triangulum elapsoides) was found only in sapling stands. The scarlet snake (Cemophora coccinea copei) was found in all forest stand classes.

The ringneck (Diadophis punctatus), brown (Storeria dekayi wrightorum), worm (Carphophis amoenus), smooth earth (Virginia valeriae), and rough earth (V. striatula) snakes were probably more common than records indicated because they difficult to find. They are semi-fossorial form and usually most common in mesic conditions unde leaf litter and fallen wood (Behler and King 197 These were found by searching (turning over and going through places of refuge) or they were cau in the funnel traps. The dry spring of 1981 probably forced these snakes underground.

The rough green snake (Opheodrys aestivus) usually more abundant than reflected in these su veys. It is a semi-arboreal species that seems prefer mesic environments and consequently was m frequent in the bayheads. The green coloration arboreal habits made it difficult to find this s cies.

The eastern cottonmouth (Agkistrodon piscivorus) was a common snake, especially in the wet bayheads. The banded water snake (Nerodia fasciata) and glossy water snake (Regina rigida) were the only water snakes recorded; the banded ater snake occurred in bayheads while the glossy ater snake occurred in sapling stands. The only ud snake (*Farancia abacura reinwardti*) noted was uring a nocturnal search of a bayhead area. This nake is usually associated with water and was only xpected to be found in the bayhead areas.

The small number of eastern coachwhips *Masticophis flagellum*) captured or observed indiates that they are uncommon in the study area. hey usually prefer dry upland habitats and were ound in regeneration, sapling and pole stands. he black pine snake (*Pituophis melanoleucus odingi*) was found in pole and sawtimber stands; his species prefers open, dry pine uplands (Behler nd King 1979). The corn snake (*Elaphe guttata*) nd rat snake (*E. obsoleta spiloides*) are usually ost common in areas where forest and agriculture ix. The corn snake was found only in bayheads hile the rat snake was found in all the upland orest classes. The pine woods (*Radineae flaviloa*) and southeastern crowned (*Tantilla coronata*) nakes were found in all upland sites, while the ibbon (*Thammophis sauritus*) and eastern garter (*T. irtalis*) snakes were found in uplands and bayheads he eastern hognose (*Heterodon platyrhinos*) and outhern hognose (*H. sinus*) snakes were found only n regeneration, sapling and pole stands.

The southern copperhead (*Agkistrodon conortrix*) was rare, being found only in a hilly awtimber stand. Possibly the study area was too andy for the copperhead. The eastern diamondback attlesnake (*Crotalus adamanteus*) was the most bundant of the poisonous snakes. As temperatures ncreased in the spring, it became more nocturnal; t was found in regeneration, sapling, pole and awtimber stands. The gopher tortoise was also ound in similar areas and may be habitat assoiated. Only one coral snake (*Micrurus fulvius*) as found in a pole stand.

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Inventory of Mammals and Birds on Bigfoot and Airey Grazing Allotments of the DeSoto National Forest, Mississippi

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Abstract.--Birds and mammals were inventoried by sampling methods during 1979 and 1980 in 4 adjoining grazing units of the DeSoto National Forest, Mississippi. Seasonal differences were not observed in mammalian community composition. Seasonal differences in avian community composition were attributed to seasonal migrations of several species. However, relative abundance of Canids was much higher in late winter compared to mid-summer. This difference was presumably due to use and loss of dogs by hunters.

INTRODUCTION

There are about 7 million ha of longleaf (Pinus palustris) - slash (P. elliotti) pine forest types in the Gulf Coastal Plain from Texas to Florida (Shiflet 1980). This forest type has had a long and recently erratic grazing history. Present uses of National forests include grazing by livestock but there is little knowledge as to effects of livestock grazing on wildlife species in the longleaf-slash pine habitat. The purpose of this work was to provide baseline data on relative abundance of birds and mammals in 4 adjacent grazing allotments in this forest type in order to detect future changes in wildlife populations associated with a plan to study livestock grazing management practices.

METHODS

Four management units comprising over 21 sections (13,886 acres) in the southern part of the DeSoto National Forest, Mississippi, were sampled for birds, small mammals, and medium-sized mammals during 1979 and 1980 (Fig. 1). Specific units compared were in the Bigfoot grazing allotment (units 1-3) and the Airey grazing allotment (unit 4). The forest was dominated by longleaf and slash (Pinus palustris) and elliottii) pine. Understory vegetation was dominated by bluestem grasses (Andropogon spp.) and wiregrass (Aristida spp.) Dominant shrubs included yaupon (Ilex vomitoria and gallberry (I. glabra). Results from 2 additional years of small mammal inventory in relation to habitat types was reported by Wolf and Lohoefner (1983).

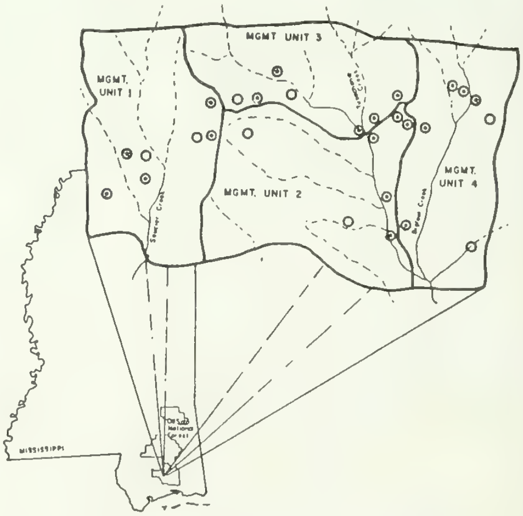

Figure 1. Location of study area showing locations of grazing management units and small mammal sampling sites. Open circles were sampled during 1979; circles with stars were sampled during 1981-82.

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Table 1. Average (± SD) density (d) and percent frequency (%) for birds on the DeSoto National Forest, Mississippi during July 1979. Averages were computed from 4 areas. Density is number of birds per sample station.

Species	d	% f
Bobwhite (*Colinus viginianus*)	0.5 ± 0.1	38 ± 11
Yellow billed cuckoo* (*Coccyzus americanus*)	0.7 ± 0.1	58 ± 12
Blue jay (*Cyanocitta cristata*)	1.1 ± 0.2	77 ± 6
Common crow (*Corvus brachyrhychos*)	1.4 ± 0.2	80 ± 8
Fish crow* (*Corvus ossifragus*)	0.2 ± 0.1	17 ± 7
Tufted titmouse* (*Parus bicolor*)	0.8 ± 0.1	62 ± 8
Carolina wren (*Thryothorus ludovicianus*)	0.7 ± 0.2	48 ± 16
Red-eyed vireo* (*Vireo olivaceus*)	0.3 ± 0.2	26 ± 12
Northern Cardinal (*Cardinalis cardinalis*)	1.2 ± 0.2	74 ± 10
Wood thrush* (*Hylocichla mustelina*)	0.2 ± 0.2	18 ± 9
Great crested flycatcher* (*Myiarchus criuitus*)	0.6 ± 0.2	52 ± 16
White-eyed vireo* (*Virio griseus*)	0.5 ± 0.2	40 ± 11
Yellow-throated vireo* (*Virio flavifrons*)	0.1 ± 0.1	15 ± 8
Kentucky warbler* (*Oporornis formosus*)	0.2 ± 0.2	13 ± 7
Rufous-sided towhee (*Pipilo erythrophthalmus*)	1.1 ± 0.4	66 ± 13
Hooded warbler* (*Wilsonia citrina*)	0.6 ± 0.2	39 ± 9
Pileated woodpecker (*Dryocopus pileatus*)	0.5 ± 0.1	44 ± 5
Brown thrasher (*Toxostoma rufum*)	0.3 ± 0.2	24 ± 9
Red-bellied woodpecker* (*Melanerpes carolinus*)	0.4 ± 0.2	39 ± 20
Brown-headed nuthatch* (*Sitta pusilla*)	0.3 ± 0.2	19 ± 12
Purple martin* (*Progne subis*)	0.2 ± 0.1	20 ± 6
Carolina chickadee* (*Parus carolinensis*)	0.2 ± 0.1	17 ± 5
Summer tanager* (*Piranga rubra*)	0.1 ± 0.1	12 ± 3
Downy woodpecker (*Picoides pubescens*)	< 0.1	1 ± 4
Pine warbler* (*Dendroica pinus*)	0.5 ± 0.3	44 ± 12
Yellow-breasted chat* (*Icteria virens*)	0.5 ± 0.5	38 ± 32
Ruby-throated hummingbird* (*Archilochus colubris*)	< 0.1	2 ± 2
Prairie warbler* (*Dendroica discolor*)	0.2 ± 0.2	14 ± 2
Red-shouldered hawk* (*Buteo lineatus*)	< 0.1	7 ± 4
Indigo bunting* (*Passerina cyanea*)	< 0.1	4 ± 5
Bachman's sparrow* (*Aimophila aestivalis*)	0.3 ± 0.2	20 ± 14
Blue-gray gnatcatcher* (*Polioptila caerulea*)	0.1 ± 0.2	8 ± 11
Chimney swift* (*Chaetura pelagica*)	< 0.1	3 ± 3
Eastern kingbird* (*Tyrannus tryannus*)	< 0.1	2 ± 4
Common flicker* (*Colaptes auratus*)	0.1 ± 0.3	16 ± 16
Orchard oriole* (*Icterus spurius*)	< 0.1	1
Hairy woodpecker* (*Picoides villosus*)	< 0.1	3 ± 2

Table 1. Continued.

Species	d	% f
Eastern wood pewee* (*Contopus virens*)	< 0.1	8 ± 10
Blue grosbeak* (*Guiraca caerulea*)	< 0.1	11 ± 14
Cattle egret* (*Bubulcus ibis*)	0.1 ± 0.7	1
Mourning dove* (*Zenaida macroura*)	0.2 ± 0.2	18 ± 16
Chuck-will's-widow* (*Caprimulgus carolinensis*)	< 0.1	3 ± 2
Barn swallow* (*Hirundo rustica*)	0.1 ± 0.2	9 ± 7
Common yellowthroat* (*Geothypis trichas*)	0.2 ± 0.2	20 ± 18
Bank swallow* (*Hirundo rusticus*)	< 0.1	6 ± 7
Eastern bluebird* (*Sialia sialis*)	0.1 ± 0.2	14 ± 13
Common grackle* (*Quiscalus quiscula*)	0.2 ± 0.2	10 ± 11
Red-headed woodpecker (*Melanerpes erythrocephalus*)	< 0.1	5 ± 6
Green heron* (*Butorides striatus*)	< 0.1	1
Broad-winged hawk* (*Buteo platypterus*)	< 0.1	5 ± 6
Barred owl* (*Strix varia*)	< 0.1	6 ± 9
Swainson's warbler* (*Limnothlypis swansonii*)	< 0.1	1
Red-winged blackbird* (*Agelaius phoeniceus*)	< 0.1	2 ± 3
Brown-headed cowbird* (*Molothrus ater*)	< 0.1	1
Common nighthawk* (*Chordeiles minor*)	< 0.1	1

*These species were not detected in mid-winter sampling plots. Additional species found during winter were White-throated Sparrow (*Zonotrichia*, American Goldfinch (*Carduelis tristis*), Eastern Phoebe (*Sayornis phoebe*), Field Sparrow (*Spizella pusilla*), Robin (*Turdus migratorius*), Ruby-crowned Kinglet (*Regulus calendula*), Chipping Sparrow (*Spizella passerina*), Myrtle Warbler (*Dendroica coronata*), Sparrow Hawk (*Falco sparverius*), Brown Creeper (*Certhia americana*), and Hermit Thrush (*Catharus guttatus*).

eeding Bird Studies

Bird data were recorded from each of 5 ansect lines in each of the 4 allotments for a tal of 20 transect lines. Breeding bird data re recorded in July 1979. On each transect ne, 5 sampling stations located about 1300 m art were each sampled once. Data were corded from each sampling station for one -minute period either by tape recorder, direct servation or both. Data were compared among rect observation, monaural tape recorder and ereo tape recorder methods for 69 stations. l stations were sampled between 5:45 a.m. and :30 a.m.

all Mammal Studies

Small mammal trap lines were sampled from y 9 - 26, 1979. Traps were checked daily and l animals removed. Two sampling lines, each th 25 stations, were used in each of the 4 eas for a total of 8 lines and 200 trapping ations. A total of 3600 trap nights was used the sampling. Trap stations were 20 m apart d each station included a pitfall trap (sunken e-gallon tin can) and a large Sherman live ap. Traps were baited with a mixture of 80 rcent oat flakes, 10 percent peanut butter, d 10 percent sardines in peanut oil. Trapping ssions lasted for 18 days with all lines run ncurrently.

dium-sized Mammal Studies

During July 1979 and January 1980, 1000 ent-posts were sampled for a total of 2000 ent-post nights. Scent posts were 1 m^2 rcular areas along secondary roads and were eaned with a rake the day before sampling. e center of each scent-post was baited with a all stick soaked with fox urine as an tractant. Scent posts were distributed at 0-m intervals with 50 stations in each of the land units. Each station was sampled for 5 nsecutive nights each season. All wildlife acks that occurred were recorded the following y. Data are reported as relative frequency of currence.

RESULTS

eeding-Bird Studies

The average (± SD) 15-minute sampling ation produced 17.6 ± 6.6 birds when recorded observer, 14.3 ± 3.4 when recorded by stereo pe and 10.8 ± 3.7 when recorded by monaural pe. Two bird species were recorded that were t previously known to nest as far south in ssissippi. A Louisiana Waterthrush was found the Highway 67 bridge over Saucier Creek and a Swainson's Warbler was found during July in a swampy portion of area IV (Airey Allotment). Nests were not found but the presence of singing males suggested that the birds were probably breeding in the area. Eastern Wood Pewees and Kentucky Warblers, thought to be rare in the area, were common (Table 1). There were no significant differences among the 4 sampling areas in July.

Small Mammal Studies

Cotton mice accounted for most of the small mammals captured (Table 2). Other mammals captured during the study were southeastern shrew, short-tailed shrew, least shrew and cotton rat. However, with more intensive sampling Wolfe and Lohoefner (1983) also captured golden mice (*Ochotomys nuttalli*), harvest mice (*Reithrodontomys humulis*), wood rats (*Neotoma floridana*), rice rats (*Oryzomys palustris*), pine voles (*Microtus pinetorum*) and house mice (*Mus musculus*). Data for the original survey were not sufficient for evaluation of relative abundance of most species among the 4 areas. However, species composition and abundance of cotton mice was similar among the 4 study units. With the additional work, Wolfe and Lohoefner (1983) failed to find significant differences among the 4 units in small mammal abundance or species richness.

Table 2. Number of small mammals trapped on DeSoto National Forest during a 18-day period, May 1979.

	Area			
Species	I	II	III	IV
Southeastern shrew (*Sorex Longirostris*)	1	1	2	0
Short-tailed shrew (*Blarina brevicauda*)	0	6	3	1
Least shrew (*Cryptotis parva*)	0	0	2	1
Cotton mouse (*Peromyscus gossypinus*)	18	18	20	21
Cotton rat (*Sigmodon hispidus*)	0	0	1	0

Medium-Sized Mammal Studies

During July 1979 and January 1980, tracks from canids, skunks, armadillos, bobcats, deer, rabbits, squirrels, racoons, opossums and domestic cats were found in the scent-post stations (Table 3). Relative abundance of tracks from different species was similar among the 4 study units. Domestic cat and opossum tracks were not detected in July, and tracks from canids were significantly more abundant in January. Tracks from other species were more abundant in January than in July but differences were not significant. We presume that the higher number of dog tracks found in January was from use and loss of dogs by hunters.

Table 3. Relative ($\bar{X}$ ± SD) frequency of tracks in scent-post stations on the DeSoto National Forest.

Species	July 1979 (%)	January 1980 (%)
Canids (*Canis* spp.)	3.8 ± 2.4	32.3 ± 13.2
Skunks (*Mephitus mephitus*)	1.1 ± 0.9	1.6 ± 1.2
Armadillos (*Dasypus novemcinctus*)	6.4 ± 4.0	9.1 ± 2.1
Bobcats (*Felis rufus*)	2.3 ± 1.2	0.6 ± 0.7
Deer (*Odocoileus virginianus*)	3.4 ± 2.0	4.1 ± 1.5
Rabbits (*Sylvilagus* spp.)	2.3 ± 1.3	4.0 ± 2.2
Squirrels (*Sciurus* spp.)	1.7 ± 0.9	6.0 ± 3.3
Racoons (*Procyon lotor*)	1.1 ± 0.7	1.6 ± 1.3
Opossum (*Didephis marsupialis*)	- - -	1.6 ± 0.9
Domestic cat (*Felis domesticus*)	- - -	0.4 ± 0.6

CONCLUSIONS

Data from the inventory of birds and mammals on the DeSoto National Forest suggest that there are no significant differences in bird and mammal communities among the 4 pastures. Future sampling to detect differences due to experimental treatments would probably be best for birds and mammals if performed in summer. However, small mammal sampling should be done in early summer (May) and with greater intensity than was done in the present study. However, winter sampling would also be adequate for detecting differences but less likely to be well-coordinated if graduate research associat are used via university grants because of thei usual coursework assignments.

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The Small Mammal Fauna of a Longleaf-Slash Pine Forest in Southern Mississippi

James L. Wolfe and Ren Lohoefener

Abstract.--Four management units comprising over 51 square km (20 square mi) in the southern part of DeSoto National Forest, Mississippi, were sampled for small mammals over a four-year period. Trap lines, consisting of 25 pitfalls and 25 traps, were used for 18 days per session. Five sessions were conducted over the period, accounting for a total of 28,800 trap-station days. Three sessions (10,800 trap-station days) were nonspecific with relation to habitat. Two sessions (18,000 trap-station nights) sampled 5 habitat (regeneration areas, seedling and sapling areas, poletimber, sawtimber and bayheads) equally.

Bayheads yielded the greatest numbers of small mammals; regeneration areas produced the fewest. The pine forest types were similar, but poletimber produced slightly more small mammals than the others. Year to year fluctuation in total captures was significant. A geobotanical ranking scale was found useful in characterizing habitat preferences of individual species.

The cotton mouse (*Peromyscus gossypinus*) accounted for 78% of the small mammal sample. Other species taken, in decreasing order of abundance, were *Cryptotis parva*, *Sigmodon hispidus*, *Sorex longirostris*, *Blarina carolinensis*, *Ochrotomys nuttalli*, *Reithrodontomys humulis*, *Neotoma floridana*, *Oryzomys palustris*, *Microtus pinetorum* and *Mus musculus*.

INTRODUCTION

Much of the lower Gulf Coastal Plain is com- osed of the longleaf (*Pinus palustris*)-slash (*P. lliottii*) pine forest type which extends from Texas o Florida. Its area is estimated at about seven illion hectares (Shiflet 1980). It is a major orest community of the southeast, important in ommercial timber production and as a unique biolo- ical community. In Mississippi, this forest asso- iation is predominant in the Pine Hills and Lower oastal Plain physiographical provinces (Lowe 1921; ross et al. 1974; Lohoefener and Altig 1983).

Hamilton and Cook (1940) stated "...small mam- als, long considered only as unfavorable species, re an unrecognized asset in forest management." his statement referred to their value as insect redators, their position in the food web, and to he role of their burrows in aeration and hydration of the soil. More recently, their importance as the critical agents of dispersal for spores of hypogeous, mycorrhizal forest fungi has been documented (Maser et al. 1978). Given the symbiotic relationship between mycorrhizal fungi and higher plants (Marks and Kozlowski 1973; Sanders et al. 1975) small mammals undoubtedly contribute to forest productivity and are of considerable economic value.

In addition to their aesthetic and indirect economic value, small mammals can be useful indicators of changes in ecosystem structure. Several characteristics of this faunal element make it well suited for environmental analysis. Habitat orientation and locomotory adaptations include semiaquatic, fossorial, arboreal and terrestrial. Insectivores, carnivores, omnivores and several classes of herbivores are represented. Thus, certain components of this fauna are sensitive to

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ompilers' note: This article was originally published in and reprinted by permission from the 1983 ournal of the Mississippi Academy of Sciences, Vol. 28(5): 37-47, Mississippi State, MS 39762.

almost any type of habitat alteration. An additional consideration is that small mammals are much less vagile than birds and larger mammals, and are thus more representative to specific habitat type. Small mammals have been shown to constitute over 90% of the diet of some raptorial birds (Craighead and Craighead 1969; Jemison and Chabreck 1962). Mammalian carnivores often prey heavily on small mammals (Hamilton and Whitaker 1979). There are approximately a dozen species of small mammals (shrews, mice, and rats) which would be expected to exist in DeSoto National Forest (Wolfe 1971; Kennedy et al. 1974; Hall 1981). Our study contributes to a characterization of this assemblage.

METHODS

The study area, situated in northern Harrison and southern Stone counties, Mississippi is shown in fig. 1. It is within the boundaries of DeSoto National Forest. Topographically it consists of gently rolling pinelands dissected by small streams (some intermittent) bordered by narrow zones of hardwoods. The understory of the pine forest is dominated by bluestem grasses (*Andropogon* spp.) and wiregrass (*Aristida* spp.). Dominant shrubs include yaupon (*Ilex vomitoria*) in upland areas and gallberry (*Ilex glabra*) in lower, less well drained areas (Stewart 1981). Understory throughout the study area is relatively sparse, as control burning is routinely practiced at three to five year intervals.

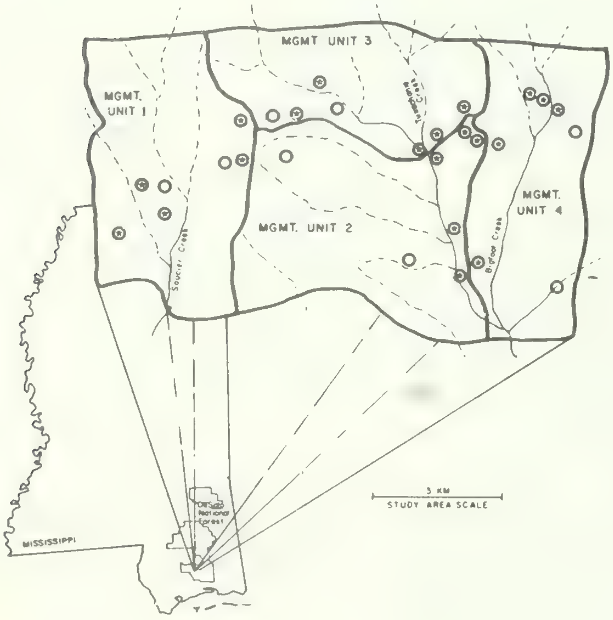

Figure 1.--Map of study area. Open circles represent sampling sites during 1979-80; circles with stars sampling sites during 1981-82.

The mammal sampling was divided into two phases. In the early phase (1979-80) two traplines were used in each of four forest range management units which ranged from about 1100 to 1700 ha in area. Traplines were superimposed on Stewart's (1981) randomly established vegetation sampling transects. Although situated predominantly in mature pine forests, traplines frequently passed through more than one major plant association and were designated as nonhabitat-specific. These lines were trapped in May, 1979, December-January 1980 and May 1980. During this phase of study geobotanical data were recorded for each trapping station. These data were analyzed in relation to mammal captures. Geobotanical analysis is discussed in more detail in the results sections.

During the second phase of sampling (1981-82) twenty traplines were used, five in each of the four management units. Within each unit, five habitat types were sampled. This habitat-specific sampling regime provided data on five habitats with four replicates of each. These lines were sampled in May 1981 and May 1982.

Specific habitats sampled during 1981-82 included clearcuts (regeneration areas), seedlings and saplings, poletimber, sawtimber, and bayheads. The first four refer to pine and represent timber stand classifications used by the U. S. Forest Service. Bayheads are areas of mesic-hydric hardwoods along small watercourses where sweetbay (*Magnolia virginiana*) is often dominant. Stewart (1981) presents a more detailed (botanical and physical) description of these classifications.

Traplines consisted of 25 stations with a 20 interval between stations. During 1979-80, each station included a pitfall trap (sunken one-gallon tin can) and a large Sherman live trap. During 1981-82, Museum Special snap traps were alternated with live traps. Traps were baited with a mixture of 80 percent oat flakes, 10 percent peanut butter and 10 percent sardines in soybean oil. Sampling sessions consisted of 18 consecutive days with al lines run concurrently.

RESULTS

Seven hundred sixty-six small mammals representing 11 species were captured. Total sampling effort was 28,800 trap-station days. Species collected, in decreasing order of abundance were: cotton mouse (*Peromyscus gossypinus*), least shrew (*Cryptotis parva*), cotton rat (*Sigmodon hispidus*) southeastern shrew (*Sorex longirostris*), short tailed shrew (*Blarina carolinensis*), golden mouse (*Ochrotomys nuttalli*), harvest mouse (*Reithrodontomys humulis*), wood rat (*Neotoma floridana*), rice rat (*Oryzomys palustris*), pine vole (*Microtus pinetorum*), and house mouse (*Mus musculus*). The relative abundance of small mammals based on our total sample is shown in Table 1. Juvenile opossums (*Didelphis virginiana*) and cotton tail rabbits (*Sylvilagus floridanus*) were trapped occasionally but are not included in our analyses.

able 1.--Numbers of mammals captured in DeSoto National Forest. The Nonspecific column is based on three sampling sessions in 1979-80 which were not segregated by habitat. Specific habitats were sampled in 1981 and 1982

Species	Totals	Nonspecific	Regeneration	Saplings	Poletimber	Sawtimber	Bayheads
eromyscus gossypinus	594	376	16	26	64	42	70
ryptotis parva	51	11	10	7	8	12	3
igmodon hispidus	30	9	6	8	2	4	1
orex longirostris	25	8	0	2	6	1	8
larina carolinensis	22	13	0	4	1	1	3
chrotomys nuttalli	12	16	0	0	0	0	4
eithrodontomys humulis	20	4	1	4	2	1	0
eotoma floridana	5	4	0	0	0	0	1
ryzomys palustris	4	4	0	0	0	0	0
icrotus pinetorum	2	2	0	0	0	0	0
us musculus	1	0	1	0	0	0	0
OTAL	766	447	34	51	83	61	90

Table 2 presents data on the total number of nimals and species (species richness) captured in he late spring (May) of four consecutive years. s can be seen, year to year fluctuations in abun-ance are significant ($X^2 = 8.08$, $P < .05$). The ost productive year produced 3.9 times as many nimals per effort as the least productive year. ompared to an average abundance of 11.8 percent, nnual fluctuations ranged from 3.4 percent to 61.8 ercent, with a mean of 32.5 percent.

Sampling effort in all management units was qual and simultaneous. Thus total captures over he four year period and species richness can be ompared. This provided a measurement (Table 3) of niformity of distribution over a large (5,619 ha, bout 51 sq km) geographic area of similar habitat.

While total captures appeared lower in unit I, Chi-square test did not detect a significant verall difference among units ($X^2 = 6.64$, $.05 < P$ .10). However, units II, III, and IV were very lose (table 3). Thus, most of the Chi-square value as derived from the low number of captures in unit , suggesting a possible lower abundance of small ammals in that area. There was no significant ifference in species richness among units ($X^2 =$ 75, $P > .25$).

Although the difference between years in abso-ute numbers taken was significant, distribution hrough habitats was similar in 1981 and 1982 and ears were combined in an analysis of habitat dif-erences. There was a highly significant dif-erence between habitats ($X^2 = 29.1$, $P < .001$) in umbers taken (table 4).

Table 2.--Fluctuations in number of animals and species collected in late spring of four consecutive years. The index is total captures/number of lines

Year	Species richness	Total captures	Traplines	Abundance index
1979	5	98	8	12.2
1980	9	153	8	19.1
1981	7	98	20	4.9
1982	7	221	20	11.1

Table 3.--Total captures and species richness by management unit

Item	Management unit			
	I	II	III	IV
Species richness	7	10	8	7
Total captures	165	203	213	196

Table 4.--Numbers of small mammals captured by habitat type

Year	Regeneration	Saplings	Poletimber	Sawtimber	Bayheads
1981	14	12	27	19	26
1982	20	39	56	42	64
TOTAL	34	51	83	61	90

Table 5.--Habitat characteristics and rankings assigned

Characteristic	Rank
Soil Drainage	
Xeric	0
Mesic	2
Grass Abundance (expressed as % ground cover)	
0 - 25	1
26 - 50	2
51 - 75	3
76 - 100	4
Litter abundance (only dead plant material as % ground cover)	
0 - 25	1
26 - 50	2
51 - 75	3
76 - 100	4
Other vascular plants	
Absent	0
Present	1
Abundant	2
Dominant tree type	
Pines	-2
Hardwoods	2
Woody vegetation growth form	
Sapling pines only	-2
Mature pines only	-1
Pines and deciduous shrubs	0
Mature hardwoods only	1
Mature hardwoods and shrubs	2
Shrubs only	3

The sample of *Peromyscus gossypinus* was sufficient for a separate analysis of habitat preference. We assumed that no interaction between management units and habitats existed and a two-way ANOVA without replication was performed. A significant habitat effect on *P. gossypinus* captures was indicated (F = 5.79, P < .01). Differences among management units was not significant (F = 1.27, P > .25). This mouse was taken most frequently in mature forests, especially bayheads (table 1).

A series of botanical and physical parameters were analyzed in relation to small mammal abundance (table 5). The scale was designed to provide a xeric-mesic gradient. Rankings were based on a summation of measurements taken within a 2.5 m radius of each trapping station during the 1979-80 trapping sessions. Low geobotanical scores indicate dry, open, well-drained habitats. Higher scores indicate a progression toward forests wit increasing understory and little accumulation.

Kendall's Tau Rank Correlation (Conover 197 was used to assess the relationships between mam captures and geobotanical class. Total captures all species was independent of geobotanical habi ranking (K = .035, test value = 1). This result would be expected if individual species were adapted to different zones along the gradient. tests of individual species, only *P. gossypinus* captures were significantly correlated with geob tanical ranking (K = .195, test value = 3772, P .025).

able 6.--Results of interfaced Chi-square test for relationship of small mammal captures to habitat characteristics as indicated by geobotanical ranking

Mammal Species	Geobotanical Class[1/] 4	5	6	7	8	9	10	11	Overall
eromyscus gossypinus	*-	ns	ns	***+	***+	ns	*-	***	***
Ochrotomys nuttalli	ns	ns	ns	ns+	ns+	ns	ns	ns	*
Reithrodontomys humulis	ns	ns	ns+	ns	ns	ns	ns	ns	ns
Sigmodon hispidus	ns	ns	ns	ns	ns+	ns	ns	ns	ns
Neotoma floridana	ns	ns	ns	ns	ns	ns+	ns	ns	ns
Oryzomys palustris	ns	ns	ns	ns	ns+	ns	ns+	ns	ns
Sorex longirostris	ns	ns	ns	ns	ns+	ns	ns	ns	ns
Blarina carolinensis	ns-	ns	ns	ns	**	ns	ns	ns	***
Cryptotis parva	ns	ns+	ns	ns+	ns	ns	ns	ns	**
Mus musculus	ns	ns	ns+	ns	ns	ns	ns	ns	ns
TOTAL									***

[1/] ns = not significant, *= significant at .05 alpha, **= significant at .01 alpha, ***= significant at .001 alpha, += more than expected, -= less than expected

In an effort to establish the location of individual species on the geobotanical gradient, an interfaced Chi-square analysis (Conover 1971) was performed (table 6).

More *P. gossypinus* was captured at the middle and high (mesic/hydric) rankings than expected and less were captured at the low (xeric) ranking than expected. More *O. nuttali*, *S. hispidus*, *N. floridana*, *O. palustris*, and *S. longirostris* were captured at the middle rankings than were expected. *B. carolinensis* was most abundant at stations of middle ranking and less abundant than expected at stations of low ranking. *C. parva* was captured most often at the drier trapping stations. Overall, lowest densities and diversities seemed to occur at both ends of the scale--xeric and hydric.

DISCUSSION

The most common species in the forests we sampled was *P. gossypinus*, comprising 78 percent of all captures. The study area was within the geographic range of its sibling species, *P. leucopus*. Our sample was a homogenous population of *P. gossypinus*--like individuals. Studies on these two species have been numerous (Wolfe and Linzey 1977; Lohmeier 1981) and their evolutionary relationship is complex.

While *P. gossypinus* was most abundant in mesic to hydric habitats, it was also the most common species in relatively open pine forests. This species shows a strong preference for pine mast (Hatchell 1964) and in May was frequently found in areas that had burned the previous winter. Layne (1974) noted that this is a pioneering species in the reinvasion of burned pinelands.

Three shrews, *C. parva*, *B. carolinensis*, and *S. longirostris* comprised a significant (13%) portion of the fauna. *Cryptotis* occupied more open, xeric areas, while *Sorex* tended toward more mesic, forested habitats. *Blarina* was ubiquitous.

Cotton rats, *S. hispidus*, typically occupied areas of dense ground cover. In certain parts of their range they are numerous in pine forests with dense understory (Layne 1974). They were much less common in the areas we sampled than would be expected on the basis of available suitable habitat. Dramatic long-term population fluctuations have been reported for this species (Odum 1955; Cameron and Spencer 1981) but we would have expected sampling over four years to detect at least one period of high density.

Next in abundance were *O. nuttalli* and *R. humulis*. *Ochrotomys* preferred closed forests or heavy brush while *Reithrodontomys* was found in grassy ground cover such as occurs in regeneration areas and open forests.

Woodrats, *N. floridana*, were not common and occurred only in swamps and bayheads. The semi-aquatic rice rat, *O. palustris*, was equally rare. The pine mouse, *M. pinetorum* is essentially subterranean and difficult to capture. We took only two in the course of the study. The relative remoteness of our study areas accounts for the fact that no old world rats (*Rattus*) and only one house mouse (*Mus*) were taken.

The results of our sampling indicates that the small mammal fauna is relatively uniform over a large geographic area of predominantly longleaf-slash pine forest. This uniformity was somewhat surprising as the areas we sampled were different in burning history and grazing intensity.

Year to year fluctuations were pronounced and should be taken into account in any attempt to assess a small mammal population over a limited time frame. Seasonal differences undoubtedly occur, but as we had only one winter sample, seasonality could not be evaluated.

Bayheads were the best overall small mammal habitats and likely act as crucial refuges in times of timber harvest, site preparation, and burning. Regeneration areas provided to be the poorest small mammal habitat. This was unexpected as early successional areas often have high populations. Two factors may be involved. First, cotton rat populations were extremely low, and this species is the most common inhabitant of early successional areas. Secondly, ground cover on the regeneration areas we sampled developed at an atypically slow rate. Three of the four areas were sandy, dry, and relatively open. Grazing may have been a factor. The pine forests, from saplings to sawtimber were statistically similiar, although the poletimber areas seemed to have a disproportionately large number of captures.

Meaningful comparisons of abundance based on similar studies in southeastern pine forests are difficult because of differences in methodologies and because of the significance of year to year fluctuations. However, relative abundance of species should be less affected by these problems. Unfortunately, few published studies have provided quantitative data on small mammals in southeastern pine forests. This may be because pine forests are generally perceived as poor small mammal habitat (Golley et al. 1965). Shadowen (1963) found a loblolly (P. taeda)-shortleaf (P. echinata) pine forest in northern Louisiana to be dominated by O. nuttalli, with P. gossypinus about half as abundant. Blarina brevicauda (= carolinensis) was intermediate between the two. Reithrodontomys fulvescens and M. pinetorum were present but rare. Hatchell (1964) working in the same area and habitat found Blarina equal to O. nuttalli in numbers and about two-thirds as many P. gossypinus. Also R. fulvescens was somewhat more common than in the Shadowen (1963) study. Atkeson and Johnson (1979) found S. hispidus to be the most common mammal in young loblolly pine plantations in Georgia. Second in abundance was P. leucopus. M. musculus, R. humulis, and O. nuttalli were also taken. Layne (1974) found S. hispidus, C. parva, P. gossypinus, R. humulis, Rattus rattus, and O. palustris, in order of abundance, in a Florida pine flatwoods. Sigmodon comprised 77 percent of all captures.

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Fish Diversity and Abundance in Streams of the DeSoto National Forest in Mississippi

Henry A. Pearson, James L. Wolfe, and Renne R. Lohoefenner

Abstract.--Twenty-six species of fish representing 11 families were collected and identified during a 1981 survey of four Southern Evaluation Project units on the DeSoto National Forest.

INTRODUCTION

In the Western United States, improper grazing ractices have been shown to alter the character of atural water; this can easily lead to altered fish opulations (Platts 1978). It has been hypothesized hat land management practices such as grazing or imber harvesting can alter fish populations by:) increasing sedimentation, (2) altering channel haracteristics, (3) increasing the level of solar adiation, (4) altering the amount of organic ebris in the water, (5) modifying the substrate, nd (6) changing the amount of terrestrial and quatic invertebrate biomass in the water.

In October, 1981, a survey was performed in he four Southern Evaluation Project units of the irey Allotment, Biloxi Ranger District, DeSoto ational Forest, Mississippi. The objective of the urvey was to document species of fish in the atural drainages and obtain an estimate of their bundance. This information can serve as a base or future evaluations of the impact of various and management practices.

STUDY AREA

Fish collecting sites were located on Saucier, olf, Bigfoot, Tuxachanie, Bridge, and several nnamed streams traversing four management units of he DeSoto National Forest (Wolfe and Lohoefener 983). Stream depth was usually less than 3 ft, ith widths varying from 10 to 50 ft; sampled tream length varied from 150 to 350 ft. Legal escriptions of sample sites, road numbers, and tream names are listed in table 1. Sufficient ater was not found in the interiors of management nits 1 and 3 (fig. 1). However, water was present ust off these units along FS 401 and FS 402; fish ollected at those sites (1-1, 1-2, 1-4, 3-2, 3-3, nd 3-4) were probably representative of fish that ould have been in the interiors of units 1 and 3 uring wetter years or seasons.

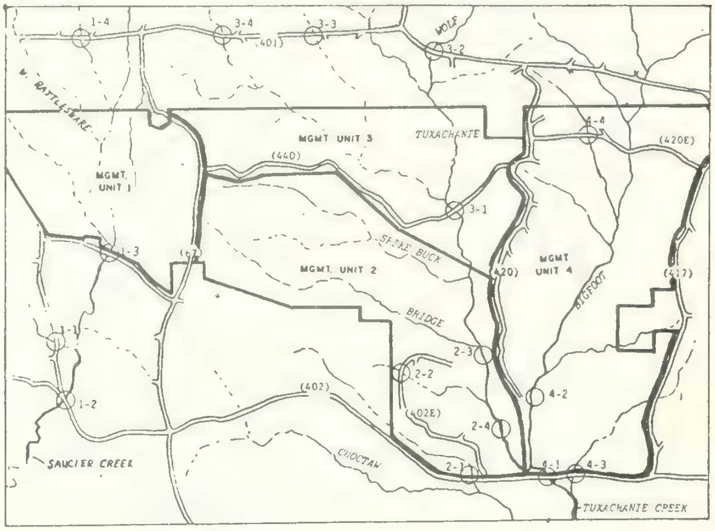

Figure 1.--Fish collecting sites (circles), access roads (in parentheses), and named streams in DeSoto National Forest, Mississippi.

Water and bottom substrates were characterized on each site (table 2). The streams at collection sites 1-2, 1-4, 2-4, 4-1, and 4-2 were clear and flowing (lotic), with sand or gravel substrates. Sites 2-2, 1-1, 1-4, 3-3, and 4-4 were characterized by clear or stained (colored) water that most likely occurred intermittently during dry seasons. Site 3-1 was similar to these five but had firmer channel substrates and water was found here throughout the year. Sites 1-3, 2-3, and 3-4 were typified by still (lentic) shallow water over a soft substrate with some deep holes present. Sites 2-1 and 4-3 had intermittent bodies of deeper water over a soft substrate.

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Table 1--Fish sample locations, DeSoto National Forest, Stone and Harrison Counties, Mississippi

Site	Location (Intersection)
1-1	Unnumbered road and unnamed creek in T.4S, R.11W, Sec. 34.
1-2	Road 402 and Saucier Creek in T.5S, R.11W, Sec. 3.
1-3	Unnumbered road and Saucier Creek in T.5S, R.11W, Sec. 27.
1-4	Road 401 and unnamed creek in T.4S, R.11W, center Sec. 15.
2-1	Road 402 and unnamed creek in T.5S, R.10W, Sec. 5.
2-2	Road 402E and unnamed creek in T.4S, R.10W, jct. Secs. 31 and 32.
2-3	Bigfoot Horse Trail and Bridge Creek in T.4S, R.10W, Sec. 32.
2-4	Natural waterfall on the Tuxachanie Creek about 165 ft north of the confluence of the Bigfoot Creek in T.5S, R.10W, Sec. 4.
3-1	Road 440 and Tuxachanie Creek in T.4S, R.10W, Sec. 29.
3-2	Road 401 and Wolf Creek in T.4S, R.10W, Sec. 17.
3-3	Road 401 and Tuxachanie Creek in T.4S, R.10W, Sec. 18.
3-4	Road 401 and unnamed creek in T.4S, R.11W, Sec. 13.
4-1	Road 402 and Tuxachanie Creek in T.5S, R.10W, Sec. 4.
4-2	Bigfoot Creek about 115 ft north of its confluence with Tuxachanie Creek in T.5S, R.10W, Sec. 4.
4-3	Road 402 and in unnamed creek in T.5S, R.10W, jct. Secs. 3 and 4.
4-4	Road 420E and Bigfoot Creek in T.4S, R10W, Sec. 22.

Table 2.--Water and substrata characteristics of streams sampled

	Water						Bottom strata				
	Depth		Shallow	Deep				Aquatic		Debris	
Site	Min.	Max.	(<1.0 ft)	(>1.0 ft)	Type	Quality	Streambed	plants	Roots	Fine	Large
	----Feet----		------Percent-------								
1-1	1.0	2.5	60	40	lentic	stained	sand	x	x	x	
1-2	0.3	2.5	75	25	lotic	clear	sand/gravel			x	x
1-3	0.2	3.3	20	80	lentic	stained	clay	x	x	x	
1-4	0.8	4.9	30	70	lotic	clear	sand/gravel	x	x	x	
2-1	0.3	2.5	10	90	lentic	clear	clay			x	x
2-2	0.7	2.0	05	95	lentic	clear	clay	x	x	x	
2-3	0.8	6.5	10	90	lentic	turbid	clay		x	x	
2-4	0.2	3.3	65	35	lotic	clear	sand/clay	x	x	x	
3-1	0.1	4.9	40	60	lotic	clear	gravel/clay		x	x	
3-2	0.7	6.5	30	70	lotic	stained	clay	x	x	x	
3-3	0.3	3.3	10	90	lentic	turbid	clay	x	x	x	
3-4	0.7	4.9	10	90	lentic	turbid	clay	x	x	x	
4-1	0.2	3.3	70	30	lotic	clear	sand/gravel		x	x	
4-2	0.2	2.5	90	10	lotic	clear	sandy			x	
4-3	1.0	3.3	05	95	lentic	turbid	clay	x	x	x	x
4-4	0.8	1.6	05	95	lentic	stained	gravel	x	x	x	

METHODS AND PROCEDURES

Fish sampling was accomplished during 2 days, ctober 5 and October 12, 1981. October 5 was a unny and calm day; October 12 was a cloudy and alm day. Water temperature throughout the ollection period was 24 ± 2 °C.

Fish were collected by electrofishing and dip etting. A backpack electroshocker with a gas owered generator was used (Model BP-1C, Coffelt lectronics Co., Inc., Englewood, CO) with direct urrent at about 150 watts (400 volts). All sites ere electrofished. Usually the streams were so aden with snags and debris that a seine could not e used. In the two instances when seining was sed (table 3), no species of fish were collected hat had not been previously collected by electroishing. Collected fish were field-fixed in 10-ercent formalin; these fish were later washed and reserved in 40-percent isopropyl alcohol and tored at the Mississippi State University Research enter, National Space Technology Laboratory tation, Mississippi.

References used to name and identify fishes ollected during this survey were: Blair and others 1968), Cook (1959), Douglas (1974), Eddy and nderhill (1969), Lee and others (1980), and mith-Vaniz (1968).

RESULTS AND DISCUSSION

Twenty-six species of fish representing 11 amilies were collected (table 4). Most species ad been reported earlier from Mississippi (Seehorn 975); some had not been previously reported. orensen's index was used to obtain similarity alues (Odum 1971). Management units 2 and 4 were he most similar in terms of fish species collected rom drainage waters (table 5). This was as expected, because both are part of the Tuxachanie Creek watershed. Management units 1 and 2 were second in terms of fish similarity; Saucier Creek and Tuxachanie Creek, which traversed the two units, were of similar quality. Other management units had similar fish indexes. Comparison of fish diversity among sites showed sites 2-2 and 3-1 to have the greatest similarity (63 percent) (table 6). Ten sites had fish species' similarity indexes of 40 percent or greater, while 9 sites had no similarity.

COLLECTED FISH SPECIES

Representative specimens were collected from 11 fish families; some species were found on all four management units and a few were found on only one unit (table 4). The following sections list the species collected by family along with other pertinent information.

Family Petromyzontidae

One lamprey larva (ammocoete) was collected in management unit 2 that could not be identified to species; it was probably *Ichthyomyzon gagei*, the southern brook lamphrey. Four species of lampreys may be found in Mississippi waters: parasitic chestnut lamprey (*I. castaneus*), parasitic silver lamprey (*I. unicuspis*) (known only from the Mississippi River), and two nonparasitic forms--the southern brook lamprey and least brook lamprey (*Lampetra aepyptera*).

Family Anguillidae

Two specimens of American eel (*Anguilla rostrata*) were collected: one in management unit 1 and one in management unit 4. This eel is a catadromous species that moves into freshwater prior to an oceanic migration. Eels were often observed but rarely collected.

Table 3.--Stream sample methods

Site	Date sampled in 1981	Seining		Electrofishing			
						D.C.	
		Area	Time	Area	Time	Watts	Volts
		ft^2	minutes	ft^2	minutes		
1-1	5 Oct	--	--	118	25	150	400
1-2	12 Oct	--	--	4304	35	150	400
1-3	5 Oct	--	--	968	20	150	400
1-4	12 Oct	--	--	269	15	150	350
2-1	5 Oct	--	--	108	15	280	400
2-2	5 Oct	--	--	226	20	140	400
2-3	5 Oct	--	--	215	25	150	400
2-4	12 Oct	430	10	1130	40	125	400
3-1	12 Oct	--	--	269	15	150	350
3-2	12 Oct	--	--	377	20	150	400
3-3	12 Oct	--	--	646	25	175	350
3-4	12 Oct	--	--	194	15	150	400
4-1	5 Oct	1400	15	4412	45	150	400
4-2	12 Oct	--	--	1184	20	150	500
4-3	12 Oct	--	--	807	20	125	400
4-4	5 Oct	--	--	301	35	150	400

Table 4.--Numbers of fish collected at the 16 study sites in the 4 management units

Species	Study Site Number															
	1-1	1-2	1-3	1-4	2-1	2-2	2-3	2-4	3-1	3-2	3-3	3-4	4-1	4-2	4-3	4
Ichthyomyzon spp. Lamprey		1														
Anguilla rostrata American eel		1														
Esox americanus Redfin pickerel				1		3			3	4	1			1	1	
Notropis roseipinnis Cherryfin shiner		7	12					13					24	1		
N. signipinnis Flagfin shiner		1	1	4				3	1					3		
N. texanus Weed shiner								7					30	2		
Erimyzon sucetta Lake chubsucker	1	1	3	2		3	2					1		1	1	
Moxostoma poecilurum Blacktail redhorse								1					3			
Ictalurus natalis Yellow bullhead				1		1								1		
Noturus funebris Black madtom													1			
N. leptacanthus Speckled madtom								2					1	1		
Aphredoderus sayanus Pirate perch							1			1	1				1	
Fundulus notatus Blackstrip topminnow			3				3									1
F. notti Starhead topminnow	5				2	4		1	1	8		9	1		1	
F. olivaceous Blackspotted topminnow		28				2		7	2		1		18	8		2
Labidesthes sicculus Brook silverside			7					20			1		20			1
Elassoma zonatum Pygmy sunfish												1			1	
Lepomis gulosus Warmouth		1								1	2	1	2	1	5	
L. macrochirus Bluegill				1						1						
L. marginatus Dollar sunfish			1			1										
L. megalotis Longear sunfish		6					1	1	4			1	15		8	
L. punctatus Spotted sunfish	1					2		2	1		2					2
Lepomis sp. Juvenile sunfish	1	7				1		3		5		1		10		2
Micropterus punctulatus Spotted bass		1														
Etheostoma proeliare Cypress darter													1	1		
E. swaini Gulf darter		1						1								
Percina nigrofasciata Blackbanded darter		2														
TOTAL (417)	8	57	27	9	2	17	7	61	12	20	8	14	116	30	18	11

Table 5.--Comparison by Sorensen's index of similarity1/ of fish species collected in the four management units

Management Unit	Management Unit 2	 3	 4
1	72	58	67
2		64	79
3			62

1/ Odum (1971).

ble 6.--Comparison of sites by Jaccard's index of similarity1/ of fish from the 16 collecting sites

ite	Site 1-2	1-3	1-4	2-1	2-2	2-3	2-4	3-1	3-2	3-3	3-4	4-1	4-2	4-3	4-4
-1	07	13	17	33	43	14	33	50	13	13	29	08	09	29	11
-2		13	06	00	19	14	33	20	13	13	29	16	40	20	19
-3			10	00	08	25	20	09	20	09	20	06	25	09	18
-4				00	38	14	00	25	25	11	11	00	18	25	10
-1					14	00	08	17	17	00	17	10	00	17	00
-2						10	27	63	30	30	30	13	33	30	40
-3							07	25	25	11	25	08	08	43	10
-4								14	13	13	13	47	31	13	27
-1									20	33	33	23	25	50	30
-2										33	33	07	25	50	18
-3											09	23	25	25	30
-4												23	25	50	08
-1													27	23	13
-2														25	23
-3															08

/ Mueller-Dombois and Ellenberg (1974).

Family Esocidae

Sixteen pickerel of two subspecies (Esox mericanus americanus and E.a. vermiculatus) were ollected.

Family Cyprinidae

The cherryfin shiner (Notropis roseipinnis) s common in small Coastal Plain streams that flow ver a sand or gravel substrate. Fifty-seven herryfin shiners were collected in three of the our management units. The flagfin shiner (N. ignipinnis) prefers larger streams and is more ommon in stained water. Thirteen flagfin shiners ere collected in all four management units. The eed shiner (N. texanus) was found in larger treams with sandy substrates; 39 were collected rom 2 range units.

Family Catostomidae

Of the 15 Erimyzon spp. adults collected, all ere lake chubsuckers (E. sucetta). They were found in all range units. Although many juvenile Erimyzon spp. were collected, some may have been sharpfin chubsuckers (E. tenuis). However, most specimens were taken in still (lentic) water--a characteristic of E. sucetta. Chubsuckers may be a good indicator of habitat quality because they are intolerant of stream siltation (Boschung and others 1983).

The blacktail redhorse (Moxostoma poecilurum) is most common in medium-sized streams with gravel bottoms. Only four redhorses were collected in two management units.

Family Ictaluridae

The yellow bullhead (Ictalurus natalis) is commonly found in small, vegetated bodies of clear water. Three bullheads were collected in three of the four management units. The black madtom (Norturus funebris) is not common but may be taken in small lotic streams that have sandy to gravelly bottoms. Only one black madtom was collected in management unit 4. The speckled madtom (N.

leptacanthus) tends to be more common than the black madtom in much the same habitat.

Family Aphredoderidae

The pirate perch (Aphredoderus sayanus) is common in slow or still waters with abundant aquatic plant cover. A total of four pirate perch were collected from three management units.

Family Cyprinodontidae

The blackstripe topminnow (Fundulus notatus) and blackspotted topminnow (F. olivaceous) are difficult to identify. The presence or absence of the predorsal stripe was found to be the most consistent character and seemed to separate the species in about the expected ratios (Brown 1956). Fundulus notatus and F. olivaceous both prefer lotic streams, but the latter tends to be more common in the clearer, faster flowing streams that have a hard substrate (Boschung et al. 1983). Seven blackstripe topminnows were collected from 3 management units while 68 blackspotted topminnow were collected from all 4 units.

The starhead topminnow (F. notti) is a common topminnow in still to slow-moving streams and can be found with a variety of substrates. Thirty-two starheads were collected from all four management units.

Family Atherinidae

The brook silverside (Labidesthes sicculus) is an abundant surface fish of clear, warm, slow-flowing waters. Forty-nine were collected in the 4 management units.

Family Centrarchidae

The banded pygmy sunfish (Elassoma zonatum) prefers clear, still water that is heavily vegetated. We collected only two. The warmouth (Lepomis gulosus) is common in most waters but prefers a lentic water with a soft bottom and vegetation. Thirteen were collected. The bluegill (L. macrochirus) is ubiquitous but prefers clear lentic water with vegetation; only two were collected. The dollar sunfish (L. marginatus) is much less common than L. gulosus or L. macrochirus; it prefers swamps and lentic waters. Only two were collected. The longear sunfish (L. megalotis) was the most common sunfish collected; 36 were collected in slow flowing streams. The spotted sunfish (L. punctatus) is usually fairly common in lentic to slow moving waters with dense cover, but only 10 were collected.

Juvenile sunfish that had not developed diagnostic characters were included in the category Lepomis spp. A total of 30 juveniles were collected.

The spotted bass (Micropterus punctulatus) prefers clear streams with deep pools. Only one spotted bass was collected.

Family Percidae

The cypress darter (Etheostoma proeliare) most common in lowland streams with some backwa areas, detritus, and a soft substrate. Only tw were collected. The gulf darter (E. swaini) is usually found in clear lotic streams with riffl and a gravelly or sandy substrate; two were collected. The blackbanded darter (Percina nigr fasciata) is most common in lotic, clear streams that have gravel bottoms and riffles; two were collected.

SUMMARY

The diversity of fish species found in stre at the selected sites in the four management uni of the Southern Evaluation Project, DeSoto Natio Forest, Mississippi, were sampled during a 2-day time period. A total of 417 specimens were collected, representing 11 families, 16 genera, 26 species of fish. Several species of darters (Percidae) that had been previously collected at these sites were not collected. There was no wa to be sure that all species present were collect

The minnows or shiners (Notropis spp.), chu suckers (Erimyzon spp.), madtoms (Noturus spp.), both blackspotted topminnow (Fundulus olivaceous and blackstripe topminnow (F. notatus), and dart (Etheostoma spp. and Percina spp.) are the most valuable indicators of habitat quality change. Particular attention should be given to these genera when conducting future surveys.

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Soils and Vegetation of the Longleaf/Slash Pine Forest Type, Apalachicola National Forest, Florida

George W. Tanner

ABSTRACT.--A 12,800 ac study site within the longleaf/slash pine type, Apalachicola National Forest, was surveyed to characterize overstory and understory vegetation. Seven major forest types and 17 soil series were delineated. Longleaf pine forest type occurred on 31.0% of the area while planted slash pine occurred on 23.6% of the area. Planted slash pine stands were grouped into three age categories: 9-18 yr, 19-38 yr and over 40 yr old. Titi and cypress areas, considered nongrazeable forest types, occurred on 30.0% of the area. The remaining area was in natural slash pine and savanna. Rutledge and Surrency soils were entirely associated with titi and cypress drainages and comprised 31.1% of the study site. Otherwise, Bladen (21.9%), Dunbar (14.2%), Dothan (10.0%) and Leefield (9.3%) were the major soil series.

Most longleaf stands had been commercially thinned to about 50 to 60 ft^2/ac. In these stands, mean tree age was approximately 62 years old with mean tree height of 66 ft. Growth of planted slash pine tended to be best on the wetter, Bladen soil series than on moderately or well drained soils. Natural slash pine and savanna sites generally were sparsely wooded. Snag (2.4/ac) and cavity (1.6/ac) densities were greatest in longleaf pine stands on Albany soil.

Frequent prescribed burns have kept a hardwood midstory from developing. Gallberry, runner oaks, greenbriers, and saw-palmetto were the most common understory shrubs and produced approximately 200 to 300 lb/ac where they occurred. Herbaceous biomass reached maximum values (approximately 2,500 lb/ac) within natural slash and savanna sites. A large portion of this forage was comprised of pineland threeawn and beakrush. Biomass production on these sites tended to decrease following the establishment of planted slash pine stands on them. Longleaf pine sites, though lower in herbaceous biomass, usually had a much richer assemblage of forage species.

INTRODUCTION

The rapidly increasing human population in the United States and World is placing higher demands on food and fiber products. Pine forests in the southern portion of the United States are well known or utilized for their fiber producing potential but are lesser known or utilized for their red meat producing potential. Much of th forested region has an understory component th is amenable to grazing and browsing, but little it is being utilized for red meat productio Therefore, on 25 September 1978, the Chief of t Forest Service approved the Range Evaluati Project, a project designed to determine t grazing potential within the major conifero

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st types in the south and to monitor the cts of livestock production on various hic, hydrologic, floral and faunal components the forest ecosystems. Efforts of the study rted herein addressed the floral component. purpose of the project was to inventory the rstory and overstory vegetation on a 13,000 ac a of longleaf/slash pine forest within the lachicola National Forest (ANF). The work was ducted under Cooperative Agreement No. 19-306 ween the U.S. Forest Service and the University Florida.

OBJECTIVES

The overall goal of this study was to entory the vegetation on the Apalachicola ional Forest study site prior to the tallation of four grazing treatments. To omplish this goal the following objectives were mulated:

1) To delineate the major plant communities based on overstory, forest type and soil series, and
2) To quantitatively describe species composition and cover of overstory and understory components, age, height and dbh of trees, and current year's growth of browse and herbage.

STUDY AREA DESCRIPTION

Location

This study was conducted along the western ndary of the Apalachicola National Forest (ANF) Liberty County, Florida (Figure 1). cifically, permanent study plots were located U.S. Forest Service compartments 26, 27, 28, 67, 69 and 72. The compartments were located Townships 3 and 4 South and Ranges 8 and 7 West comprised approximately 12,800 ac. This area approximately 20 mi south of Bristol, Florida ng State Road 12.

Forest types and soil series had been mapped viously by the U.S. Forest Service (Fig. 2-6). codes for the forest type (denominator) and l series (numerator) designations are given in les 1 and 2, respectively.

Climate

Total rainfall was quite variable during the r span of this study. In 1979, two hurricanes ssed near Florida in the month of September ich resulted in 18 in of rainfall being recorded Blountstown, Florida with 72.7 in for the nual total. No other major rainfall event curred during the study period. Total rainfall creased in 1980 and 1981 with 51.2 and 48.4 in, spectively. Low rainfall in April and June 1981 gmented the droughty conditions on the study e.

Air temperatures in this region usually are ld in the winter to hot in the summer. Periodic ezing temperatures associated with cold fronts are common during the winter months. July and August usually are the hottest months with air temperatures occasionally reaching 100°F.

Table 1. Code for forest type on ANF study site, Liberty County, Florida.

	Forest Type	Denominator on map code
I.	High Pineland (A. longleaf B. slash)	
	a. Turkey Oak Phase	11 A,B
	b. Bluejack Oak Phase	12 A,B
	c. Mixed Oak Phase	13 A,B
II.	Pine-Palmetto Flatwoods	
	a. Longleaf Pine Phase	21
	b. Slash Pine Phase	22
III.	Savannahs	
	a. Verbisina Phase	31
	b. Pleea Phase	32
	c. Hypericum Phase	33
IV.	High Pineland Depression	
	a. Hardwood Phase	51
	b. Holly Phase	52
	c. Cypress-Black Gum Phase	53
	d. Black Gum Phase	54
V.	Titi Swamps	
	a. Titi Phase	61
	b. Pine Titi Phase	62
VI.	Bay Swamps	
	a. Sweet Bay Phase	71
	b. Mixed Bay Swamps Phase	72
VII.	Cypress Swamps	
	a. Cypress Domes	81
	b. Cypress Black-Gum Phase	82
	c. Cypress Stringers	83
VIII.	Southern Mixed Hardwood Forest	90
IX.	River Swamps	
	a. Hydric Hardwood Swamp	101
	b. Cypress Gum Swamps	102
X.	Loblolly Pine Forest	120
XI.	Longleaf Flat	130
XII.	Slash Pine Flat	140
XIII.	Pine Plantation	150

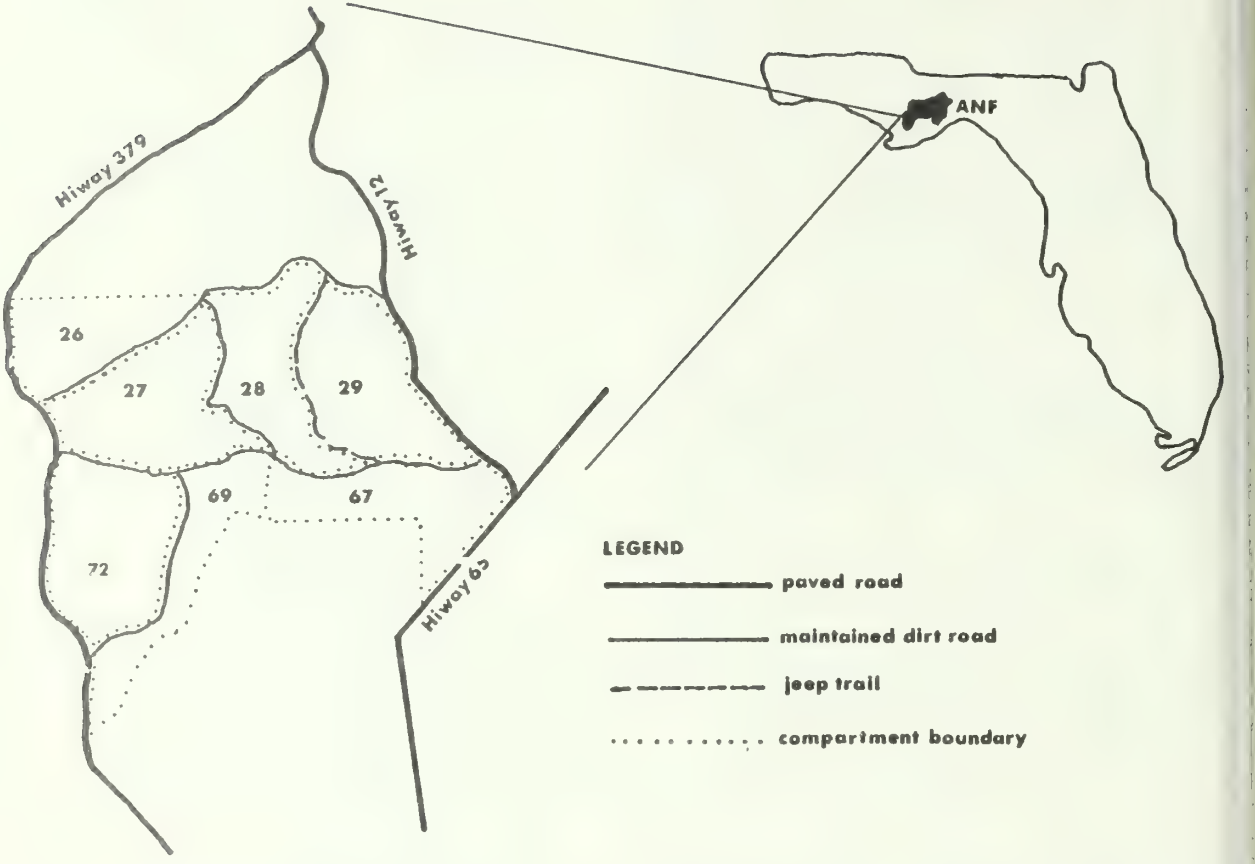

Figure 1. Location of the Apalachicola National Forest study site, Liberty County, Florida.

Geology and Soils

Geology of the ANF region was described in depth by Clewell (1971). The study site for this project and the entire ANF lies within the Gulf Coastal Lowlands land form. This land form has been divided into two physiographic units based on topography: the Apalachicola Coastal Lowlands and the Woodville Karst Plain. The study site was located in the former unit.

The bedrock of this unit is limestock and dates no later than to the early Miocene. This limestone reaches depths of approximately 200 feet near the Apalachicola River. Positioned above the bedrock, various Miocene clastics are found. Surface soils are derived from Pleistocene sands. Although the Apalachicola Coastal Lowlands are higher in elevation than the Woodville Karst Plain, they are more swampy due to a perched water table above the impenetrable bedrock.

Seventeen soil series were identified on the study area (Table 3). These soils typically have sandy loam or loamy sand surface horizons. Soils other than the well drained series have moderate amounts of clay material in the B horizons. Variation in drainage classifications ranged from very poorly drained to excessively drained. More detailed descriptions of these soil series are presented in the Appendix.

The two very poorly drained soil ser
Rutledge and Surrency, comprised 30.1% of
entire study area (Table 3). These soils
restricted to drainages. Within the Compart
28-29 pastures, these soils comprised 43.2% of
area.

Bladen soils (poorly drained) were the
two most dominant series, covering 21.9% of
area overall. This series occurred mostly in
Compartment 72 and 26-27 pastures, 39.5%
47.2%, respectively. The "somewhat po
drained" soils, mainly of the Leefield and Du
series, generally were uniformly distrib
throughout the four pastures. "Well drai
soils were least prevalent in the Compart
67-69 pasture, totaling only 6.5% of the area.

Forest Types

Forest type delineations were according
Clewell's (1971) descriptions. Seven ma
overstory forest types were located within
study area (Table 3). Clearcuts were
identifiable from the maps, however approximat
100 acres in Compartment pasture 28-29 and
acres in Compartment pasture 26-27 were clear
immediately prior to this study.

Within the entire study area, natu
longleaf pine (29.1%), planted slash pine (23.

able 2. Code for soil types on ANF study sites, iberty County, Florida.

oil Series	Numerator on map code	Drainage[1]
utledge Series	01	VPD
urrency Series	02	VPD
orovan/Pamlico Muck	03	VPD
sier	11	VPD
oxville & Rains	13	PD
iver Swamp	14	PD-SWP
umaqueptic Psammaquents	21	PD
lummer	22	PD
laden	23	PD
hipley	31	SPD
eon	32	PD
alquin	33	SPD
lbany	34	SPD
eefield	35	SPD
unbar	36	SPD
apelo	37	PD
lanton	38	MWD
rtega	40	WD
oxworth	41	MWD
ershaw	42	ED
roup	43	WD
uquay	44	WD
othan	45	WD
aceville	46	WD
lpin	47	WD-ED

[1] VPD = very poorly drained, PD = poorly drained, SPD = somewhat poorly drained, MWD = moderately well drained, WD = well drained, ED = excessively drained.

and titi swamps (23.2%) were the most dominant forest types (Table 3). Not all forest types were equally distributed among the four pastures. The remaining areas of longleaf-oak stands were found only on well and excessively drained soils and existed only in Compartment pastures 28-29 and 67-69. Approximately 450 ac of this forest type had been clearcut and planted to slash pine in Compartment pasture 28-29. Longleaf stands occurred throughout the study area but were most predominant in Compartment pastures 28-29 (1,356 ac) and 67-69 (1,174 ac). Seventy-three percent of all natural slash pine acreage was located in Compartment pasture 26-27. Planted slash pine stands also occurred throughout the study area, however, this forest type was most predominant in Compartment pastures 26-27 (28.1%) and 72 (42.3%). The savanna community, though small in acreage, is unique to this area of Florida and the ANF. The majority of this community that remained on the study site was located in Compartment pasture 72.

Titi swamps occupied 42.8 and 31.9% of Compartment pastures 28-29 and 67-69, respectively. Cypress swamps, though usually small in total acreage, were associated with the drainage standards. Their linear and/or dendritic configuration may cause problems in grazing distribution.

Each natural forest type generally was found to be strongly associated with two or three soil series. Although longleaf stands occurred on 10 of the 17 soil series, the majority of this forest type occurred on Leefield and Dunbar soils. Longleaf-oak stands were restricted solely to the very dry, deep sands. Approximately 80% of natural slash stands and 97% of the savanna was on Bladen soils. The major portion of both titi and cypress swamps was on Surrency soils.

Slash pine plantations were found on 11 of the 17 soil series. However, the majority of planted slash pine acreage was on Dunbar (40%) and Bladen (37%) soils.

VEGETATION SAMPLING

Design and Intensity

Vegetation sampling was restricted to areas of natural pine or planted pine, clearcuts to be planted to pine and a savanna. Titi and cypress swamps, the other two major communities on the study site, were not sampled since they provided very little herbaceous forage and/or were quite impenetrable by man or beast. Therefore, it was felt that these two communities would receive limited use by livestock. Clearcuts were site prepared for planting during this study. Permanent plot markers were destroyed, therefore data from these plots are incomplete.

Within those communities being inventoried, eight soil types were sampled. These eight soils represented three general drainage classifications: poorly drained, somewhat poorly drained, and moderately to excessively well drained.

Sampling Frequency and Duration

Herbage and browse were sampled during winter (Jan-Feb 1980), spring (April-May 1980) and fall (Oct-Nov 1980 and August 1981). In spring and winter, only species composition and utilization of Herbage and Browse were measured; all vegetation measurements were recorded during the fall sampling periods.

Sampling Techniques, Measurements and Descriptions

Overstory Trees

Overstory trees (stems more than 1 in DBH) were sampled by a plotless technique around each sample point. Pines were measured for 1) basal area in ft^2/ac using a ten-factor prism, 2) DBH of prism-recorded trees with a DBH tape, 3) height of a representative dominant tree with a clinometer, and 4) tree age from increment boring of the nearest tree within the northwestern quadrant at each sample point in natural stands or from U.S. Forest Service records within plantations. Snags, defined as any dead tree more than 10 ft tall and 10 inches DBH, were counted within a 33 ft radius of each sample point.

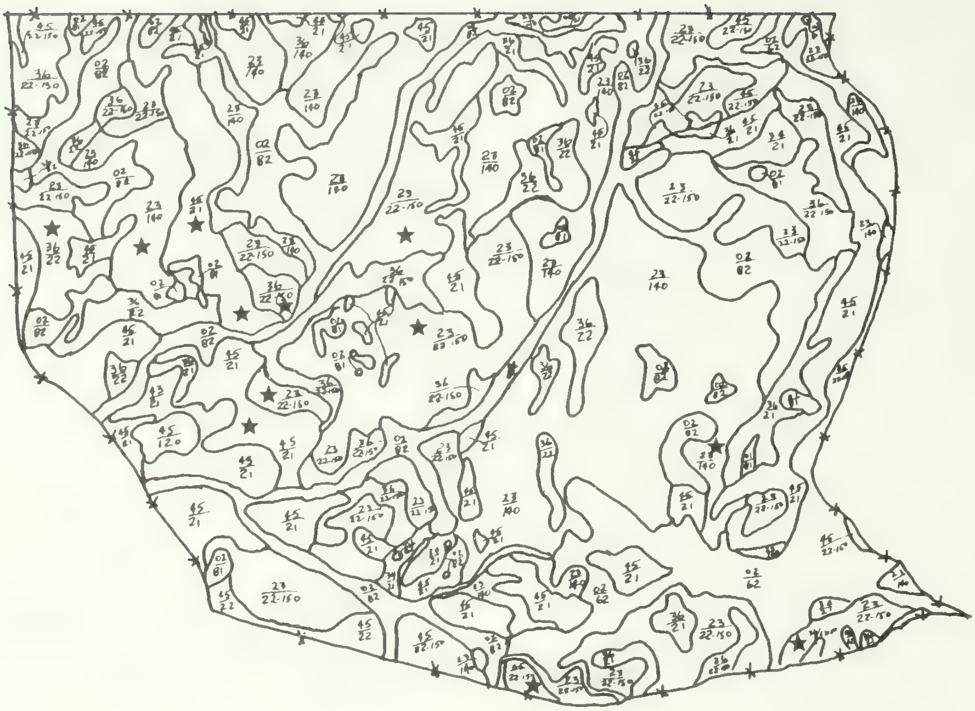

Figure 2. Forest type and soil series combinations (see Table 2 and 3 for codes) on Compartments 26 and
ANF study site, Liberty County, Florida. Stars indicate vegetative sample locations.

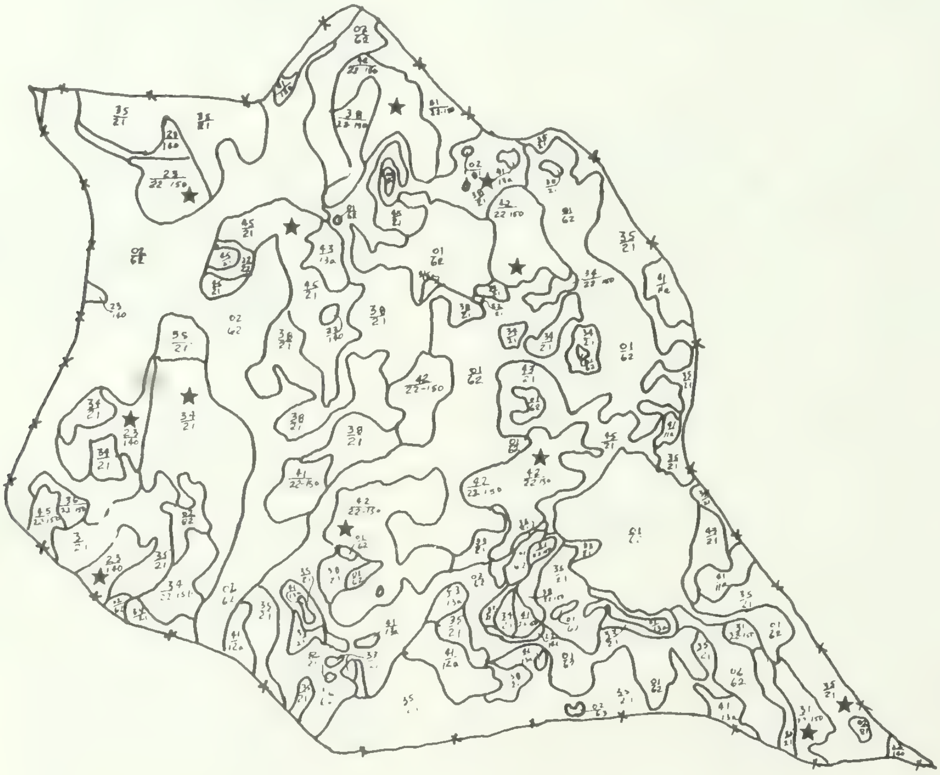

Figure 3. Forest type and soil series combinations (see Tables 2 and 3 for codes) on Compartments 28 an
29, ANF study site, Liberty County, Florida. Stars indicate vegetative sample locations.

Table 3. Overall total area (acres) and proportion (%) of overstory forest type - soil series combinations on the entire ANF study site, Liberty County, Florida.

Soil Series	Drainage[2] Class	Forest Type[1] LL-O	 LL	 NS	 PS	 Sav	 Titi	 Cypress	Total
		(Acres [Proportional])							
Rutlege	VPD						876 (6.8)	6 (T)	882 (6.9)
Surrency	VPD						2095 (16.4)	869 (6.8)	2964 (23.2)
Bladen	PD			1146 (9.0)	1123 (8.8)	529 (4.1)			2798 (21.9)
Plummer	PD			98 (0.8)	24 (0.2)	14 (0.1)			136 (1.1)
Sapelo	PD		21 (0.2)		21 (0.2)				42 (0.3)
Chipley	MWD				45 (0.4)				45 (0.4)
Talquin	PD		113 (0.9)						113 (0.9)
Albany	SPD		403 (3.1)		38 (0.3)				441 (3.4)
Leefield	SPD		1190 (9.3)						1190 (9.3)
Dunbar	SPD		463 (3.6)	141 (1.1)	1207 (9.4)				1811 (14.2)
Leon	SPD		13 (0.1)	19 (0.1)	63 (0.5)				95 (0.7)
Blanton	MWD	20 (0.2)	266 (2.1)		39 (0.3)				325 (2.5)
Foxworth	MWD	184 (1.4)			69 (0.5)				253 (2.0)
Dothan	WD		1156 (9.0)	24 (0.2)	103 (0.8)				1283 (10.0)
Troup	WD	33 (0.3)	83 (0.6)						116 (0.9)
Fuquay	WD		10 (0.1)						10 (0.1)
Kershaw	ED				294 (2.3)				294 (2.3)
Total		237 (1.9)	3718 (29.1)	1428 (11.1)	3026 (23.6)	543 (4.2)	2971 (23.2)	875 (6.8)	12,798

[1] LL-O = longleaf pine- oak, LL = longleaf pine, NS = natural slash pine, PS = planted slash pine, Sav = Savanna, Titi = Titi Swamp, Cypress = Cypress swamp.
[2] See Table 2.

idstory Trees, Shrubs and Vines

Midstory trees, shrubs and vines (stems $\leq$ 1 n DBH and > 5 ft high) were measured within ircular milacre plots (radius = 44.7 in) centered n each sample plot. Species within this category ere measured for canopy cover (%) and height (ft) y species. Also, the number of measured plants f each species was recorded.

rowse

The current year's growth of trees, shrubs, nd vines within 5 feet of the ground (browse) was easured on a 9.6 ft^2 circular plot randomly ocated in the immediate vicinity of each ermanent sample point. The center of the 9.6 ft^2 lot was located 65.7 in from permanent plot enters. Foliar cover of each browse species was cularly estimated. Species with less than 10% over were recorded as present. Current year's rowth of each browse species with greater than 0% canopy cover was collected (clipped) eparately, oven dried, and weighed to determine roduction (lbs/ac) and percent botanical omposition by weight. A three dimensional clip as used.

Herbage (grasses, grasslikes and forbs) were easured within 2, 2.7 ft^2 quadrats randomly ocated at each sample point. Total herbage eight (lb/ac) for each species rooted in the uadrat was determined by clipping and weighing in he field. A selected number of samples was eturned to the lab, dried at 60°C for 48 hr and eighed for dry weight conversions. Foliar cover of species with greater than 10% cover was ocularly estimated. Other herbage species were listed as present. Also, areal cover of litter and bareground was ocularly estimated on each quadrat.

RESULTS

Overall Species Composition

Taxonomic nomenclature followed Radford, Ahles and Bell (1968) for forbs and woody plants. Hitchcock (1935) was used for grasses.

Fourteen tree species were encountered within the sample forest type soil series combinations of the entire ANF study site (Table 4). Longleaf pine stands had nine species encountered. Bladen soils had the least number of tree species while the drier soils had more species. Several oak species were common on the drier soils.

Shrub species were more diverse and common than trees. Thirty-one shrub species were recorded on the ANF study site (Table 4). Gallberry (Ilex glabra) was the most ubiquitous shrub species, occurring to some degree in all forest type - soil series combinations except PS9--Chipley. Bedding of Bladen soils in PS9 and PS19 stands appeared to be responsible for the increased occurrence of gallberry over NS sites. PS39 sites were not bedded and gallberry was not as common. Gallberry occurrence appeared to be diminishing on Dunbar soils planted to slash pine. This trend was not as evident on Dothan soils.

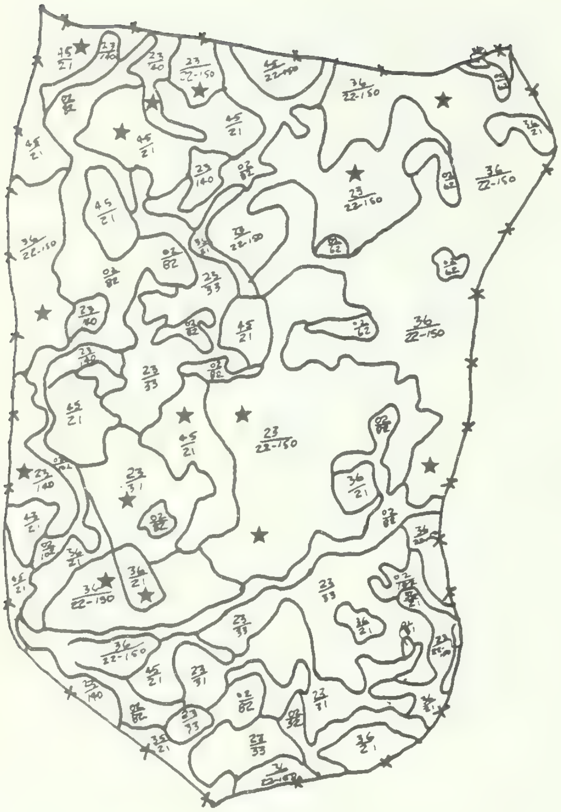

Figure 4. Forest type and soil series combinations (see Tables 2 and 3 for codes) on Compartment 72, ANF study site, Liberty County, Florida. Stars indicate vegetative sample locations.

Shrub occurrence generally was much l
frequent on Balden soil than on the other, m
drier soils. Shrub species most common on Bla
soils were St. John's-wort (*Hypericum fasci*
latum) and blackberry (*Rubus* spp.). On the dr
soils, excluding the excessively drained Kers
series, runner oaks, gallberry and dwarf huck
berry (*Gaylussacia dumosa*) were most comm
Longleaf pine occurs naturally on these soi
Clearcutting, site preparing and planting th
sites appeared to initially increase blackbe
and ground blueberry occurrence but decre
gallberry and wax myrtle (*Myrica cerife*
occurrence.

Only nine vine species were recorded on t
ANF study site, five of which were *Smilax* spec
(Table 4). *Smilax bona-nox* was the most comm
vine.

Forty-two grass species were recorded wit
the entire ANF study site (Table 4). Pinel
threeawn (*Aristida stricta*), commonly cal
wiregrass, was the most ubiquitous grass spec
occurring in all forest type - soil ser
combinations. Low panicums, a complex of seve
Dichanthelium species, also occurred in all stu
sites. Site preparation (chopping and beddi
did not have apparent deleterious effects
wiregrass abundance. Cabanis (*Andropog*
cabanisii) and broomsedge (*A. virginicus*) were t
most common bluestems. Elliot bluestem (
gyrans) was found mostly on drier soils. B
bluestem (*A. gerardii*), a very desirable gras
was measured only in longleaf pine stands. Oth
decreaser grass species encountered on the A
study site were yellow (*Sorghastrum nutans*) a
lopsided Indian grass (*S. secundum*), switchgra
(*Panicum virgatum*) and maidencane (*P. hemitomon*)

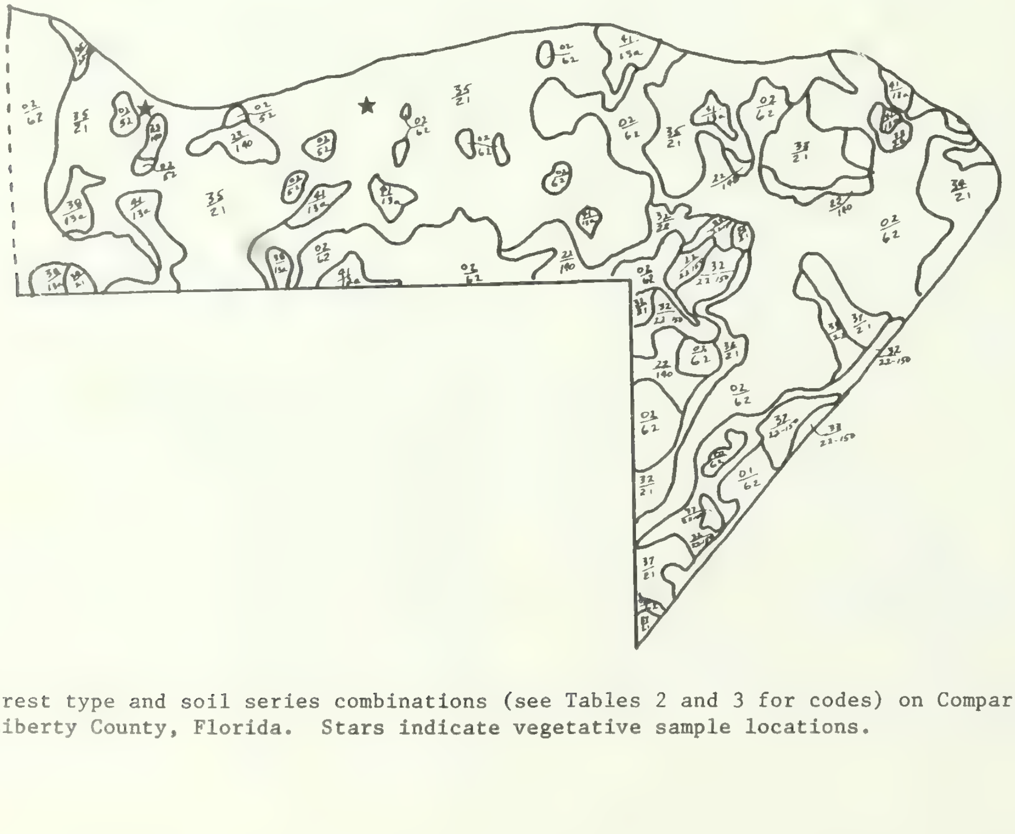

Figure 5. Forest type and soil series combinations (see Tables 2 and 3 for codes) on Compartment 67, ANF study site, Liberty County, Florida. Stars indicate vegetative sample locations.

Table 4. Number of species encountered within sampled forest type-soil series combinations within the entire ANF study site, Floria.

	Forest type-Soil series[1]																				
	LL						NS			PS9					PS19				PS39	SAV	CC	Overall
	AL	LE	DU	BT	DO	Total	BL	DU	Total	BL	CH	DU	KE	Total	BL	DU	DO	Total	BL	BL	DO	Total
Trees	2	4	2	2	7	9	1	0	1	1	3	3	5	7	4	3	2	8	4	1	2	14
Shrubs	13	12	8	12	24	26	13	5	14	17	7	16	14	28	15	15	13	19	11	5	11	31
Vines	4	7	4	3	8	8	2	0	2	1	3	1	6	6	4	5	2	7	1	0	1	9
Grasses	13	14	[illegible]	[illegible]	27	32	20	8	21	17	7	26	14	30	18	17	11	24	14	13	16	42
Grasslikes	3	4	4	3	4	5	7	4	9	4	0	8	4	9	5	5	3	6	3	3	3	11
Forbs	25	24	12	19	45	58	32	13	34	24	15	31	21	48	28	20	13	36	24	16	19	78
Legumes	7	10	4	7	10	11	0	0	0	1	4	3	7	8	6	8	5	8	2	0	6	12
Ferns	1	1	0	1	1	1	0	0	0	1	1	1	1	1	0	1	2	1	1	0	0	2
Other	3	1	1	2	3	3	2	1	2	3	2	3	3	3	3	3	2	3	3	3	2	3

Forest types:
LL = longleaf pine, NS = Natural slash pine, PS9 = Planted slash pine 9-80 yr old, PS19 = Planted slash pine 19-38 yr old, PS39 = Planted slash pine greater than 39 yr old, Sav = Savanna, CC = clearcut. Soil series: AL = Albany, BL = Bladen, BT = Blanton, CH = Chipley, DO = Dothan, DU = Dunbar, KE = Kershaw, LE = Leefield.

Cyperus, Rynchospora and Scleria species groups were the most common grasslikes encountered (Table 4). These species were seldom in flower therefore impossible to distinguish at the specific level. Grasslike species tended to be more common on the wetter Bladen soil series.

Forbs comprised the largest species group among the vegetation (Table 4). A total of 78 forb species or species groups were distinguished. Grasslike goldaster (Pityopsis graminifolia) was the most ubiquitous single species, occurring to some degree in all forest type - soil series combinations. The Aster and Solidago species groups also were recorded throughout the study area.

Native legume species were scattered throughout the study area but generally were not very common (Table 4). Pencil flower (Stylosanthes biflora) and Tephrosia spp. were two of the more common legume species. Bladen soils tended to have the fewest legumes present.

Only two fern species were recorded. Bracken fern (Pteridium aquilinum) was very abundant in the longleaf pine stands and in slash pine stands planted on the drier soils. Mushroom species were scattered throughout the ANF study site but were never very common.

Overstory Tree Parameters

For the entire ANF study site, mean tree age within sampled longleaf pine stands ranged from 56 to 78 years old (Table 5). Trees on natural slash pine sites usually were very scattered. However, one natural slash pine site in this study had a good stand of trees, averaging 24 years old. This stand may have been artificially seeded but not recorded on USFS files. Planted slash pine sites were segregated into three age groups of approximately 12, 23, and 40 years old.

Tree height was quite uniform in the longleaf pine stands, averaging between 63 and 70 ft (Table 5). Tree height of planted slash pine was affected by soil type. Minor increases in height occurred on the drier soils, while averaging tree height on Bladen soil showed about a 20 percent increase between the age categories. These increases of tree height on Bladen soils by planted slash pine resulted in taller trees (43 ± 9 ft) by age 23 than of slash pine in a natural stand (35 ± 3ft).

Average DBH within the longleaf pine stands ranged between 10.4 and 12.3 in, but was only 8.0 in the younger natural slash pine stand (Table 5). Planted slash pine on Bladen soils had larger mean DBH measurements than the drier soils for both PS9 and PS19 age groups. Mean DBH measurements for slash pine on Bladen soils apparently did not increase through time between PS19 and PS39 soils.

Most of the longleaf pine stands, had been commercially thinned and stumped. Basal area ranged from 38 to 71 ft^2/ac among the five soil series on which longleaf was sampled (Table 5). The maximum value was inflated due to unthinned longleaf stands on Leefield soils in Compartments 67-69. Mean basal area in the forested natural slash pine stand was 72 ft^2/ac.

A large disparity of mean basal area existed among the soil series in PS9 stands, ranging from 22 to 75 ft^2/ac. Chipley and Kershaw soils are very dry and not conductive to planted slash pine growth. Mean basal area of PS19 trees on Bladen soils was less than in PS9 stands. This change may have been due to death or to an original lower stocking rate. Mean basal area of PS19 stands on Dunbar and Dothan soils was about 50% greater than on Bladen soils. Mean basal area in PS39--Bladen stands was 14% greater than PS19--Bladen stands.

Overstory canopy cover of longleaf pine stands was uniform among the soil types, ranging from 41 to 49% (Table 5). The natural slash pine stand had an average 58% canopy cover. The relationship of average canopy cover among PS9 forest type - soil series combination was similar to basal areas estimates among those stands. The lowest canopy cover means were on Chipley and Kershaw soils 36 and 50%, respectively. Mean canopy cover within planted slash pine stands on

Table 5. Overall mean tree age, height, dbh, basal area, canopy cover, snag density, and cavity density within respective standard deviations, of dominant overstory trees within the sampled forest type - soil series combinations of the entire ANF study site, Florida.

Forest Type[1]	Soil Series	Age (Yr)	Height (ft)	DBH (in)	Basal Area (ft^2/ac)	Canopy Cover (%)	Snags (no./ac)	Cavities (no./ac)
LL	Albany	62	64	12.3	46	41	2.4	1.6
	Leefield	54	70	10.4	71	49	0.4	0.0
	Dunbar	78	63	12.9	57	49	0.0	0.0
	Blanton	60	66	12.0	38	41	1.4	0.0
	Dothan	56	69	11.7	57	46	1.4	0.2
NS	Bladen	24	35	8.0	72	58	0.6	0.0
PS9	Bladen	13	36	6.4	75	62	-	-
	Chipley	11	30	4.5	22	36	-	-
	Dunbar	13	26	5.0	75	63	-	-
	Kershaw	11	26	3.8	36	50	-	-
PS19	Bladen	23	43	7.0	56	66	-	-
	Dunbar	24	30	6.4	83	61	-	-
	Dothan	23	32	6.8	87	70	-	-
PS39	Bladen	40	53	7.1	64	55	0.5	0.0

[1] LL = Longleaf pine; NS = Natural slash pine; PS9 = Planted slash pine 9-18 years old; PS19 = Planted slash pine 19-38 years old; PS39 = Planted slash pine greater than 39 years old.

Bladen soils was similar among the three age categories.

This survey did not encounter many snags or cavities (Table 5). None were found in planted slash pines younger than 39 years old nor within the savannas. Of those snags and cavities tallied, the majority were in longleaf pine stands. Snag density ranged from 0.0 to 2.4/ac. Many of the snags had no cavities, probably indicating a short-lived existence of snags on this study area.

Snag density was affected by several factors. First, the requirement of a 10" dbh excluded some standing dead trees as the mean dbh of the dominant trees within the longleaf stands was about 12 in. Secondly, frequent fire causes many dead trees to burn and fall. And finally, several snags were found pushed down by stumping crews.

Future snag surveys should use belt transects and should make some record of fallen trees. Reptiles and amphibians make up a large component of Florida wildlife; therefore, fallen snags provide a significant amount of cover for these species.

Midstory

The midstory component was defined as trees, shrubs, and vines with stems greater than 1 in dbh and more than 5 ft in height. Vegetation meeting these requirements was virtually non-existent within the sampled forest type - soil series combinations. Absence of a midstory component was due to frequent prescribed burns designed and implemented to retard development of that stratum.

Understory Parameters

Browse cover was generally greater
longleaf pine than among the other forest
with browse cover on Dunbar soils (6%) being
exception (Table 6). Within slash pine st
browse cover was greatest in PS39 sites on D
soils (21%). Average browse cover never exc
13% on the somewhat poorly drained Bladen
Herbage coverage was greatest within the na
slash pine forest type, averaging 74% and 12
Bladen and Dunbar soils, respectively. He
coverage within the longleaf pine forest type
lowest on Leefield soils (26%) due mainl
recent prescribed burning in some areas
long-term lack of fire in other areas. He
coverage averaged 90% in the nearly tree
savanna.

Overall average browse biomass was highes
natural slash pine-- Dunbar (782 lb/ac)
clearcut--Dothan (397 lb/ac) forest type-
series combinations (Table 7). In both sta
gallberry was the dominant browse spec
Gallberry also contributed a large proportio
the total browse biomass in the longleaf
stands. In addition, several species of
contributed significantly to browse biomass
longleaf stands and in planted slash pine in
soils. Growth of blackberry, as well
gallberry, is stimulated by soil disturb
associated with site preparation and bedding.

Longleaf pine stands typically had
browse species present, but biomass production
limited due to frequent prescribed burn
Runner oaks, dwarf huckleberry, ground blueb
(Vaccinium myrsinites) and greenbrier had r

Table 6. Average areal cover of browse, herbage, bareground and litter within sampled forest types soil series combinations of the entire ANF study site, Florida. Data were collected October - November 1980 and August 1981.

		Forest type[1]						
Soil series	Parameter	LL	NS	PS9	PS19	PS39	Sav	CC
		%						
Bladen	Browse		5	6	13	4	9	
	Herbage		74	44	39	39	90	
	Bareground		2	2	3	0	3	
	Litter		20	51	36	44	7	
Chipley	Browse			13				
	Herbage			42				
	Bareground			20				
	Litter			17				
Albany	Browse	32						
	Herbage	48						
	Bareground	6						
	Litter	22						
Leefield	Browse	28						
	Herbage	26						
	Bareground	5						
	Litter	55						
Dunbar	Browse	6	12	16	6			
	Herbage	37	126	39	37			
	Bareground	0	0	T	0			
	Litter	51	0	51	56			
Blanton	Browse	18						
	Herbage	54						
	Bareground	13						
	Litter	14						
Kershaw	Browse			15				
	Herbage			22				
	Bareground			13				
	Litter			51				
Dothan	Browse	29			21			25
	Herbage	48			33			64
	Bareground	1			0			10
	Litter	29			27			13

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[1] LL = Longleaf pine, NS = Natural slash pine, PS9 = Planted slash pine 9-18 yr old, PS19 = Planted slash pine 19-38 yr old, PS39 = Planted slash pine greater than 39 yr old, Sav = Savanna, CC = clearcut.

Table 7. Average forage biomass within sampled forest type-soil series combinations of the entire ANF study site, Florida. Data were collected October - November 1980 and August 1981.

Soil series	Forage class	LL	NS	PS9	PS19	PS39	Sav	CC
					lb/ac			
Bladen	Browse		40	38	180	39	47	
	Herbage		1908	741	1643	1158	1875	
Chipley	Browse			114				
	Herbage			807				
Albany	Browse	271						
	Herbage	993						
Leefield	Browse	328						
	Herbage	596						
Dunbar	Browse	124	397	125	63			
	Herbage	920	2604	778	734			
Blanton	Browse	151						
	Herbage	999						
Kershaw	Browse			122				
	Herbage			192				
Dothan	Browse	269			191			721
	Herbage	1155			2336			1472

[1] LL = Longleaf pine, NS = Natural slash pine, PS9 = Planted slash pine 9-18 yr old, PS19 = Planted slash pine 19-38 yr old, PS39 = Planted slash pine greater than 39 yr old, Sav = Savanna, CC = Clearcut.

regrowth following fire and comprised a large portion of the browse biomass longleaf pine.

Average herbage biomass estimates were greater on natural slash pine - Dunbar and PS19-Dothan sites, 2604 and 2336 lb/ac, respectively (Table 7). Beakrush was the most significant contributor on natural slash pine - Dunbar sites, while pineland threeawn was the dominant herbage species on PS19-Dothan sites. Among longleaf pine stands, herbage biomass was lowest on Leefield soils. Pineland threeawn was not decimated by the site preparation methods used on this study's planted slash pine sites.

Browse and herbage biomass yields were regressed against the respective foliar cover estimates within each sampling quadrat. Browse cover (BC) accounted for 48% of the variation in browse weight (BW) and is described by the following equation:

$$BW = 13.4 + 9.9\ (BC).$$

Likewise, herbage cover (HC) accounted for the variation in herbage weight (HW) a described by the following equation:

$$HW = 68.0 + 17.4\ (HC).$$

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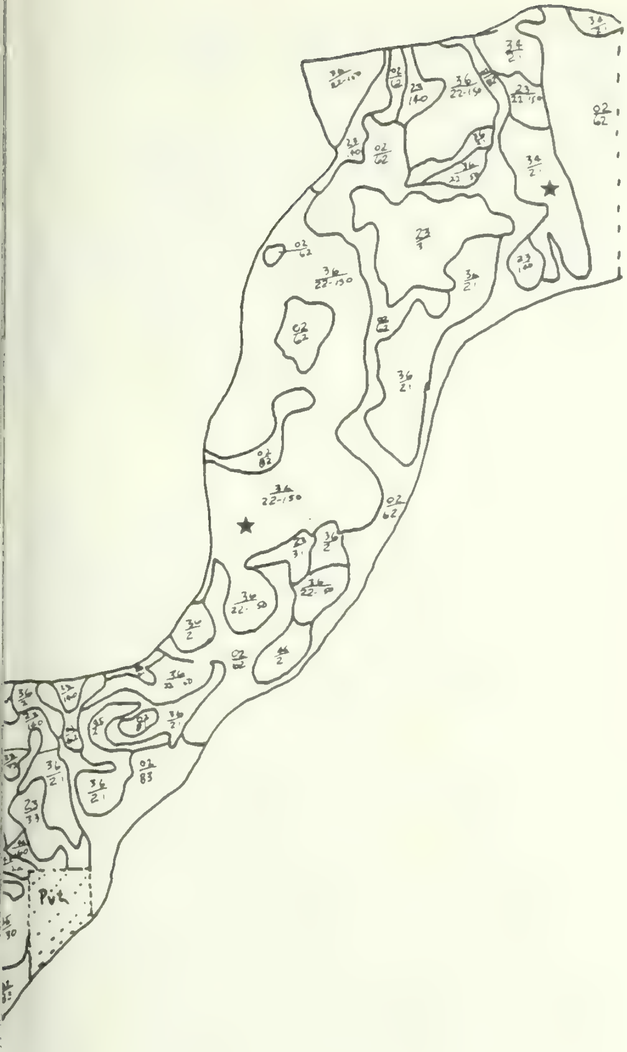

gure 6. Forest type and soil series ombinations (see Tables 2 and 3 for codes) on ompartment 69, ANF study site, Liberty County, orida. Stars indicate vegetative sample ocations.

APPENDIX

Description of those soil series found
the ANF study site, Liberty County, Florida.

RUTLEDGE SERIES

The Rutledge series is a member of the sandy, iliceous, thermic family of Typic Humaquepts. ese soils typically have black loamy sand upper horizons more than 6 inches thick, very dark ay loamy sand lower A horizons and grayish brown ttled sand C horizons.

ange in Characteristics: Reaction is very rongly acid to extremely acid throughout the soil. The A horizon is sand, fine sand, loamy sand, or loamy fine sand.

Drainage and Permeability: Very poorly drained. The water table is at or near the surface for long periods of the year, and ponding is common. Runoff is very slow or ponded. Permeability is rapid throughout.

SURRENCY SERIES

The Surrency series is a member of the loamy, siliceous, thermic family of Arenic Umbric Paleaquults. These soils have black sand A1 horizons, grayish brown A2 horizons 20 to 40 inches thick, and mottled grayish brown loamy B horizons.

Range in Characteristics: Texture of the A horizon is loamy sand or sand 20 to 40 inches thick. Texture of the Bt horizons is sandy loam to sandy clay loam. Reaction of the B horizon is very strongly acid to strongly acid.

Drainage and Permeability: Very poorly drained. The water table is at the surface for long periods of the year, and ponding is common. The permeability is rapid in the A horizon and moderate in the B horizon.

BLADEN SERIES

The Bladen series is a member of the clayey, mixed, thermic family of Typic Ochraquults. These soils have loamy A horizons, gray, fine-textured, Bt horizons containing mottles of yellowish-brown, strong brown, and shades of red, and a seasonally high water table.

Range in Characteristics: Bladen soils are strongly acid to very strongly acid in all horizons unless limed. The principal surface soil textures are sandy loam, fine sandy loam, loam, and clay loam; loamy fine sand and loamy sand are minor textures. Texture of the Bt horizon is centered on clay, but sandy clay is within the range of the series.

Drainage and Permeability: Poorly drained; permeability is slow to very slow. In most years depth to the water table is less than 15 inches for periods of 2 to 6 months. Some areas are flooded annually for periods of 1 to 2 months.

PLUMMER SERIES

The Plummer series is a member of the loamy, siliceous, thermic family of Grossarenic Paleaquults which consist of deep, poorly drained, moderately permeable soils that formed in sandy and loamy sediments of marine terraces. These soils are on level or depressional landscapes and along poorly defined drains of the Coastal Plain. They are saturated in winter, spring, and sometimes into summer. Slope is dominantly 1 percent or less, but ranges up to 5 percent.

Range in Characteristics: Reaction of all horizons ranges from extremely acid to strongly acid. The A horizon is sand, fine sand, or loamy sand. The Bt horizon is sandy loam or sandy clay loam.

Drainage and Permeability: Plummer soils are poorly drained; runoff is slow and permeability is moderately rapid in the sandy A horizon and moderate in the subsoil. A water table is above the surface or within 15 inches of the surface for very long periods, mainly in midwinter and spring; depressional phases are ponded for 6 to 12 months each year.

SAPELO SERIES

The Sapelo series is a member of the sandy, siliceous, thermic family of Ultic Haplaquods which consist of poorly drained, nearly level soils that have a fine sand upper sequence of horizons with a black A1 horizon, light gray A2 horizon, very dark brown and dark brown Bh horizon, pale yellow A'2 horizon, and a light gray sandy clay loam B'tg horizon. Slopes range from 0 to 2 percent.

Range in Characteristics: Reaction ranges from extremely acid to strongly acid. The A horizon is sand or fine sand. The B horizon is sandy loam, fine sandy loam, loam, clay loam, or sandy clay loam.

Drainage and Permeability: Poorly drained; slow runoff, moderate permeability. The water table is at 15 to 30 inches for 2 to 4 months during most years.

CHIPLEY SERIES

The Chipley series is a member of the thermic family of coated Aquic Quartzipsamments which consists of deep, moderately well-drained, rapidly permeable soils that formed in thick deposits of sandy marine sediments. They are on nearly level to sloping upland landscapes in the lower Coastal Plain. Slopes range from 0 to 8 percent.

Range in Characteristics: Texture is sand or fine sand to depths of 80 inches or more. Reaction ranges from extremely acid through medium acid in all A horizons except where limed and from very strongly acid to slightly acid in the C horizon.

Drainage and Permeability: Moderately well-drained; slow runoff; rapid permeability. These soils have seasonal water tables between depths of 20 to 40 inches for 2 to 4 months during most years.

TALQUIN SERIES

The Talquin series is a member of the sandy, siliceous, thermic family of Entic Haplaquods which consists of deep, poorly drained, moderate to moderately rapid permeable sandy soils that formed in thick beds of sandy marine sediments. They are on broad, nearly level lower Coastal Plain flatwoods. Slopes range from 0
percent.

Range in Characteristics: Texture is sand o
sand to depths of 80 inches or more. Re
ranges from extremely acid to strongly acid.

Drainage and Permeability: Talquin soil
poorly drained. Runoff is slow. Permeabil
rapid in the A horizon and moderate to mode
rapid in the Bh horizon. The water tab
within depths of 10 inches for 1 to 3
during periods of high rainfall and within
of 20 to 40 inches for 9 months or more
most years.

ALBANY SERIES

The Albany series is a member of the
siliceous, thermic family of Gross
Paleudults which consists of somewhat
drained soils that formed in Coastal
deposits of sandy material underlain by
sediments. Permeability is rapid in the
sandy surface horizon and moderate in the
subsoil. Slopes range from 0 to 5 percent.

Range in Characteristics: Reaction ranges i
Ap or A1 horizon from extremely acid to sli
acid and in the A2 and B horizons from
stronly acid to medium acid. Texture of
horizon is sand, fine sand, loamy sand, or
fine sand. Texture of the Bt horizon is
loam or sandy clay loam.

Drainage and Permeability: Somewhat
drained; seasonally high water table is with
to 30 inches of the surface for 1 to 4
yearly. Permeability is rapid in the
horizons and moderate in argillic hori
Runoff is slow. In some areas, floodin
possible under abnormal conditions.

LEEFIELD SERIES

The Leefield series is a member of the l
siliceous, thermic family of Arenic Plinth
Paleudults. These soils have thick loamy
surfaces over somewhat gleyed, loamy Bt hor
that have soft plinthite in their lower part.

Range in Characteristics: Reaction is
strongly acid in all horizons, except where
soil has been limed. The A horizon is loamy
or sand in texture. The texture of the B ho
is sandy clay loam or sandy loam.

Drainage and Permeability: Somewhat p
drained with slow runoff and slow int
drainage. A perched water table at depths
than 30 inches is present for several m
during the year. Permeability is moderate in
upper part and moderately slow in the lower p

DUNBAR SERIES

The Dunbar series is a member of the cl
kaolinitic, thermic family of Aeric Paleaquul

hese soils have dark gray sandy loam A horizons, rown and gray clayey Bt horizons, and light gray andy clay C horizons at a depth of more than five eet.

ange in Characteristics: The soil is strongly to ery strongly acid, except where it is limed. The horizon is typically sandy loam and ranges from oam to loamy sand. The Bt horizon commonly is andy clay, but it ranges from clay loam to clay.

rainage and Permeability: Somewhat poorly rained. Runoff and internal drainage are slow. ermeability is slow. Undrained areas are aturated to within less than 1 foot on the urface for significant periods every year.

LEON SERIES

The Leon series is a member of the sandy, iliceous, thermic family of Aeric Haplaquods hich consists of somewhat poorly drained, sandy oils that have a weakly cemented Bh horizon ithin 30 inches of the surface. These soils ormed in thick deposits of sandy marine sediments nd are on nealry level to gently sloping andscapes. Slopes range from 0 to 5 percent.

ange in Characteristics: Texture is sand or fine and to depths of 80 inches or more. Reaction anges from extremely to strongly acid in each orizon.

rainage and Permeability: Leon soils are omewhat poorly drained. Runoff is slow. ermeability is rapid in the A horizons and oderate to moderately rapid in the Bh horizons. he water table is at depths of 10 to 40 inches or periods of more than 9 months during most ears. It is at depths of less than 10 inches for ne to 4 months during periods of high rainfall nd recedes to depths of more than 40 inches uring very dry seasons.

BLANTON SERIES

The Blanton series is a member of the loamy, iliceous, thermic family of Grossarenic aleudults which consists of deep, moderately ell-drained, moderately permeable soils that ormed in sandy and loamy marine or eolian eposits. They are on nearly level to strongly loping upland landscapes in the Coastal Plain. lopes range from 0 to 12 percent.

ange in Characteristics: Texture of the A orizon is sand, fine sand, loamy sand, or loamy ine sand, and reaction ranges from very strongly cid to medium acid. The Bt horizon is sandy oam, fine sandy loam, or sandy clay loam.

rainage and Permeability: Moderately ell-drained; moderate permeability; rapid nternal drainage; slow runoff. A perched water able above the B2t horizon is within depths of 60 o 72 inches for 1 to 3 months in most years and elow 72 inches the remainder of the year. It ises above 60 inches briefly in some years.

FOXWORTH SERIES

The Foxworth series is a member of the thermic family of coated Typic Quartzipsamments which consists of deep, moderately well-drained, very rapidly permeable soils that formed in thick deposits of sandy marine or aeolian sediments. These are on broad, nearly level and gently sloping uplands and sloping sideslopes. They are saturated below depths of about 40 inches in winter and early spring. Water runs off the surface very slowly. Slope ranges from 0 to 8 percent.

Range in Characteristics: Thickness of sand exceeds 80 inches and texture is sand or fine sand throughout. Reaction ranges from very strongly acid to medium acid throughout.

Drainage and Permeability: Moderately well-drained. Runoff is very slow. Permeability is very rapid. A water table fluctuates between depths of 40 to 72 inches below the soil surface for 1 to 3 months during most years and 30 to 40 inches for less than 30 cumulative days in some years.

DOTHAN SERIES

The Dothan series is a member of the fine-loamy, siliceous, thermic family of Plinthic Paleudults which consists of deep, well-drained, moderately slowly permeable soils that formed in thick unconsolidated medium to fine textured sediments of the Coastal Plain. These soils are on broad, nearly level to strongly sloping uplands. Slopes range from 0 to 12 percent.

Range in Characteristics: Soil reaction is medium to very strongly acid throughout, except where the surface has been limed. Texture of the A horizon is sandy loam, fine sandy loam, loamy fine sand, or loamy sand. Texture of the B horizon is sand loam, sand clay loam, or clay loam and ranges to include sandy clay in the lower poriton of the Bt horizon.

Drainage and Permeability: Well-drained. Runoff and internal drainage are medium. Permeability is moderate in the B21t and B22t horizons and moderately slow in the horizons with plinthite.

TROUP SERIES

The Troup series is a member of the loamy, siliceous, thermic family of Grossarenic Paleudults. These soils have thick brownish sandy A horizons and red loamy Bt horizons.

Range in Characteristics: Reaction of all horizons is strongly acid or very strongly acid. Texture of the A horizon is sand or loamy sand. Thickness ranges from 40 to 72 inches. Texture of the Bt horizon is sandy loam or sandy clay loam.

Drainage and Permeability: Well-drained. Runoff is slow. Permeability is moderate to moderately rapid.

FUQUAY SERIES

The Fuquay series is a member of the loamy, siliceous, thermic family of Arenic Plinthic Paleudults. These soils have thick A horizons of loamy sand or sand textures 20 to 40 inches thick. These are underlain by loamy Bt horizons that have plinthite in the lower part.

Range in Characteristics: Reaction is very strongly acid or strongly acid throughout, except where limed. The A horizon is loamy sand, sand, or loamy fine sand. Texture of the Bt horizon is centered on sandy clay loam.

Drainage and Permeability: Well-drained. A perched water table occurs above the plinthic zone briefly during wet periods. Internal drainage is medium. Permeability is moderate in the upper part of the B horizon and slow in the lower part.

KERSHAW SERIES

The Kershaw series is a member of the thermic family of uncoated Typic Quartzipsamments and consists of deep, excessively drained, very rapidly permeable soils that formed in thick sandy deposits. These soils are on smooth uplands and dune-like landscapes and have slopes ranging from 2 to 15 percent.

Range in Characteristics: Reaction ranges from medium acid to very strongly acid. Texture is coarse sand, sand, or fine sand to a depth of more than 80 inches.

Drainage and Permeability: Excessively drained; slow runoff; very rapid permeability. Depth to seasonal water table is more than 120 inches.

Comparison of Vertebrate Wildlife Communities in Longleaf Pine and Slash Pine Habitats in North Florida

Ronald F. Labisky and Julie A. Hovis

Abstract--Birds, herpetofauna, and small mammals were surveyed on a 5,181-ha (12,797-acre) research site within natural longleaf (*Pinus palustris*) and planted slash pine (*Pinus elliottii* var. *elliotti*) habitats in the Apalachicola National Forest, Florida, during 1980 and 1981. Densities of breeding and wintering birds averaged 100.9 birds/km^2 (0.4 birds/acre) and 136.2 birds/km^2 (0.6 birds/acre), respectively, for 1980 and 1981. Densities of birds were greater ($P < 0.05$) in longleaf than in slash pine during both breeding and wintering periods. Species richness and species diversity of birds differed ($P < 0.05$) between the 2 habitat types, being greater in longleaf pine. Thirty-nine species of amphibians and reptiles, totaling 726 individuals, were captured during spring and fall surveys in 1980 and 1981. Herpetofaunal species diversity and biomass differed ($\underline{P} < 0.05$) between habitats, being greater for longleaf than slash pine. Five species of small mammals, totaling 198 individuals, were captured during the spring and fall periods of 1980 and 1981. Neither capture success, species diversity, nor biomass of small mammals differed ($\underline{P} < 0.05$) between longleaf and slash pine habitats. Birds, herpetofauna, and small mammals generally favored longleaf pine habitats over slash pine habitats, which, in light of the substantive diminishment ($> 80\%$) of longleaf pine in Florida during the past 3 decades, raises concern for the future of these vertebrate groups in the pinelands of north Florida.

INTRODUCTION

The Multiple Use-Sustained Yield Act of 1960 andated that all public lands be managed oncurrently for grazing, wildlife, recreation, nd timber (Pearson 1974). Subsequently, land anagers on national forests have begun to develop anagement strategies that consider the total orest environment. It is now recognized that a ell-balanced ecosystem approach to multiple-use anagement must include all components of the orest community--plants and animals, game and ongame, vertebrates and invertebrates, soil, limate, and other environmental factors (Clawson 975, Siderits and Radtke 1977). Yet, the uccessful implementation of such all-encompassing anagement practices is a complex procedure that inges on the ability of various land-management roups to integrate successfully their individual oals and objectives (Lewis 1973, Pearson 1974).

In the southern United States, where pproximately 65% of the nation's pulpwood is roduced (Southern Forest Institute 1977), emphasis traditionally has been placed on maximizing timber-harvest yields. In recent years, however, an expanding human population, coupled with the public's rising interest in environmental quality, has placed increased demands on the southern pine forests--not only for timber production, but also for beef production, wildlife, recreation, and wilderness. As a result, forest managers in the South have turned increasingly to sophisticated multiple-use planning to meet these growing and often conflicting demands (Lewis 1973).

The compatibility of cattle grazing with other southern pine forest uses is a controversial and, as of yet, largely unresolved issue. One aspect of this controversy, the effect that cattle grazing has on wildlife, has centered mainly on a few selected game species, particularly the white-tailed deer (*Odocoileus virginianus*) (Goodrum and Reid 1955; Lay 1967, 1969; Veteto et al. 1971; Pearson and Sternitzke 1976, 1978; Lay and Murry 1978; Mitchell 1980; Thill and Martin 1979). No study to date has

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attempted to assess the impact that cattle grazing has on the total wildlife community. As a result, the interrelationships among cattle, wildlife, and timber in southern pine forests are not understood clearly, a situation that has seriously precluded the implementation of sound resource management strategies.

The Southern Evaluation Project, approved by the Chief, U.S. Forest Service, in 1978, was designed to evaluate impacts of timber, wildlife, and range management on the biological, physical, and socio-economic components of National Forests in the South. To achieve this goal, study areas were established in Texas, Louisiana, Mississippi, and Florida. The initial phase of the comprehensive project was to obtain pretreatment baseline inventories on the study areas. The present study, conducted in 1980 and 1981, reports the abundance and species composition of birds, herpetofauna, and small mammals within natural longleaf pine and planted slash pine habitats on the Apalachicola National Forest, Florida.

STUDY AREA

The study was conducted on the western section (T3S, 4S; R7W, 8W) of the Apalachicola National Forest, which is located in the Fl Panhandle southwest of Tallahassee. Bounde the east by Florida Highway 12 and on the we Florida Highway 379, the 5,181-ha (12,797- research site consisted of 7 contiguous Forest Service management compartments: 26, 28, 29, 67, 69, and 72 (Fig. 1). compartments were subject to ongoing f management practices (e.g., prescribed burnin timber harvesting) throughout the study pe Major forest types present on the area incl natural longleaf pine (31%), planted slash (24%), titi (*Cliftonia monophylla* and *Cy* spp.) thickets (23%), natural slash pine (pondcypress (*Taxodium distichum* var. *nutans*) tupelo (*Nyssa* spp.) swamps (7%), and savannas (Tanner and Terry 1982).

The research site is approximately 18 m ft) above sea level and has a generally terrain. Soils range from very poorly draine extremely dry, with the Surrency, Bladen, Dot and Leefield series being the most common (Ta and Terry 1982). The mean annual temperature precipitation for the area are 20 C (68 F) anc cm (59 in), respectively (National Oceanic Atmospheric Administration 1978). Rainfall temperature data for the 2-year study per

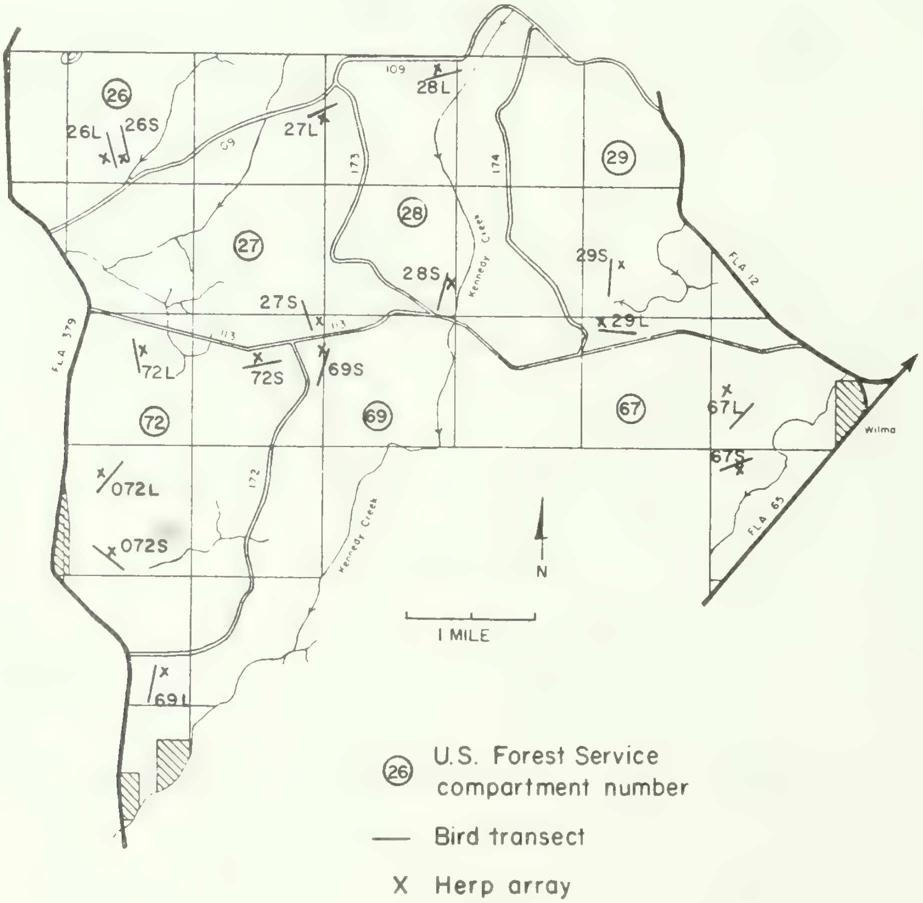


Fig. 1. Location of faunal sampling sites within natural longleaf (L) and planted slash (S) pine habitat types, Apalachicola National Forest, Florida, 1980 and 1981.

80-1981, were obtained from the weather station Blountstown, Florida, which is located proximately 32 km (20 miles) northwest of the search site (Fig. 2).

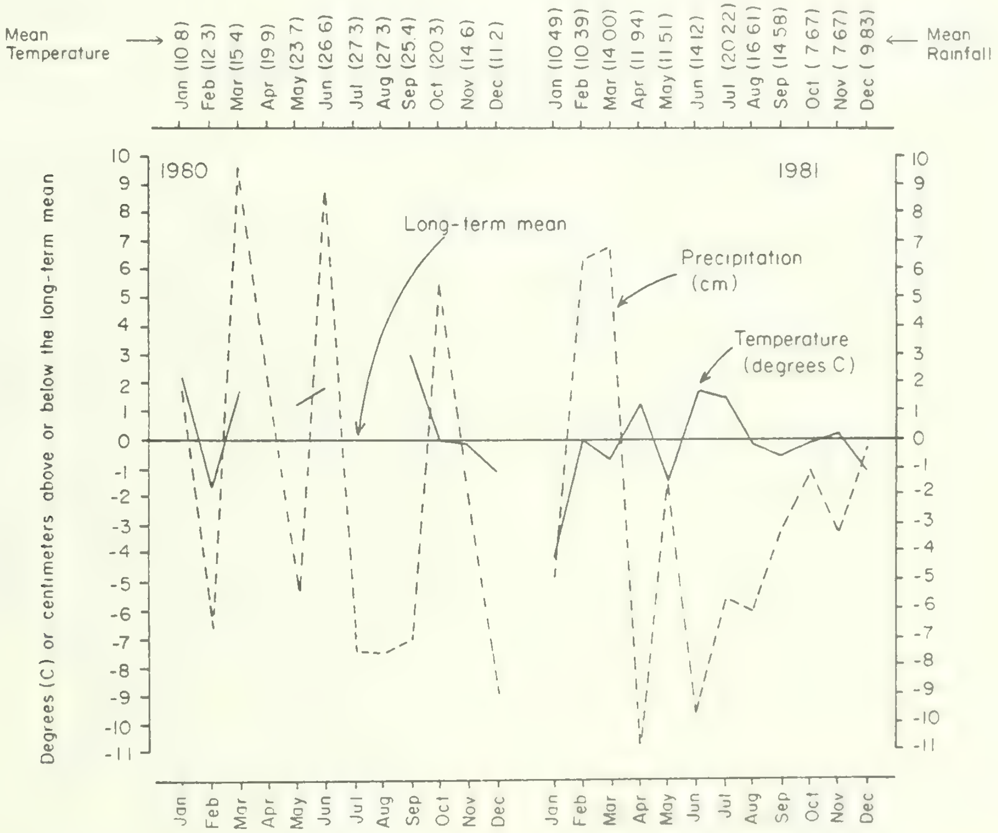
The 7 management compartments comprising the search site were grouped into 4 treatment stures, each 900 ha (2,223 acres) or larger, for e subsequent evaluation of 4 different levels of nge management: pasture A - compartments 26 and ; pasture B - compartments 28 and 29; pasture C compartments 67 and 69; and pasture D - mpartment 72, which was divided into 2 sections, signated as 72 and 072. In each of the 4 stures, 2 natural longleaf pine and 2 planted ash pine stands were selected for indepth faunal rveys (Fig. 1, Table 1). Thus, a total of 16 rest stands served as sites for censusing bird, rpetofaunal, and small mammal communities on the udy area.

METHODS

mpling Design and Procedures

Birds.--Bird populations were censused using e fixed-width strip transect method (Conner and ckson 1980). Four, 500-m (1,640-ft) transects were established in each of the 4 treatment pastures, with 2 transects being located in natural longleaf pine habitat and 2 in planted slash pine habitat (Fig. 1).

Four bird censuses were conducted on the research site--2 during the breeding season (10-18 May 1980, 7-14 May 1981), and 2 during the wintering season (11-19 December 1980, 7-18 December 1981). Each transect was censused on 5 different days within the first 4 hours post-sunrise during each sampling period. The order in which transects were censused was varied to minimize time-of-day biases in bird detectability. Bird observations (sight or call) were recorded only within the 20-m (66 ft) zone extending from each side of the transect. Each bird observed was identified to species, and its location in the census strip was recorded. These data were used to determine the density (number of individuals observed/km^2), species richness (number of species observed), species diversity (H') (Shannon and Weaver 1949), and biomass (kg) of birds observed within each strip transect during each of the 4 sampling periods. Biomass values were estimated using mean standard weights of individual species as reported in the literature (Appendix A.1).



ig. 2. Departures from long-term mean monthly measurements of temperature and precipitation, Apalachicola ational Forest study area, 1980 and 1981. Long-term means of temperature (top left) and precipitation (top ight) are for the period 1941-1970. Temperature measurements for April, July, and August, 1980, were not vailable. All data are for Blountstown, Florida (U.S. Department of Commerce 1980, 1981), which is located pproximately 32 km (20 miles) northwest of the study area.

Table 1. Characteristics of forest stands containing the 16 faunal sampling sites, Apalachicola National Forest, Florida, 1980 and 1981.

Management compartment and pasture	Stand characteristics[a/]					
	Habitat type[c/]	Stand number	Size (ha)	Age (years)	Soil type[d/]	Soil wetness rank[e/]
26A	LP	08	477	54	Dothan	2
	SP	09	104	10	Dunbar	4
27A	LP	10	101	109	Dothan	2
	SP	02	79	10	Bladen	5
28B	LP	05	230	48	Leefield	4
	SP	18	104	19	Albany	4
29B	LP	04	358	57	Leefield	4
	SP	06	37	11	Kersaw	1
67C	LP	06	247	88	Dothan	2
	SP	02	1930	23	Dunbar	4
69C	LP	07	89	103	Dothan	2
	SP	09	27	16	Dunbar	4
72D	LP	04	1806	63	Leefield	4
	SP	07	289	17	Leon	5
072D	LP	19	180	88	Dunbar	4
	SP	07	128	24	Dunbar	4

[a/] Obtained from U.S. Forest Service, Apalachicola Ranger District (unpublished data).

[b/] Compartments followed by the same letter comprise a pasture; compartment 72 was divided into 2 sections, designated as 72 and 072.

[c/] LP = natural longleaf pine; SP = planted slash pine.

[d/] See Tanner and Terry (1982) for complete description of soil series.

[e/] Soil wetness rank: 0 = xeric, 5 = saturated.

Herpetofauna.--Herpetofauna were sampled using an array-type trapping system (Campbell and Christman 1977). Each array consisted of 4, 7.6-m (25-ft) metal drift fences (30 cm [12 in] above ground in height), positioned in a plus-shaped pattern with a central separation of 15 m (49 ft). Four funnel traps, constructed of aluminum-screen wire, were positioned along each of the 4 drift fences, which provided for a total of 16 traps per array. Within each of the 4 treatment pastures, 2 arrays were placed in natural longleaf pine habitat and 2 in planted slash pine habitat (Fig. 1).

Arrays were operative for 8 consecutive weeks during 4 seasonal trapping periods: spring 1980 (13 March - 15 May); fall 1980 (3 September - 1 November); spring 1981 (29 March - 20 May); and fall 1981 (4 September - 30 October). Arrays were checked weekly during operation. Captured animals were identified to species, weighed (g), and measured -- snout to vent length (mm). The date of capture, location of trapping-array (pasture, compartment, and habitat type), and funnel-trap number (1-16) in which the animal was captured were recorded also. Herpetofaunal specimens were deposited in the Florida State Museum, Gainesville, Florida. Trapping results were used to determine the number of individuals captured per array during each of the 4 trapping periods. In addition, species richness (number of species captured), species diversity (H') (Shannon and Weaver 1949), and biomass (g) of herpetofauna were determined.

Small Mammals.--Small mammals were sampled using removal-trapping. Four traplines, 2 in natural longleaf pine habitat and 2 in planted slash pine habitat, were established in each of the 4 treatment pastures parallel to the corresponding bird census transect (Fig. 1). Each trapline consisted of 25 trap-stations, spaced at 15-m (49-ft) intervals. A trap-station was comprised of 1 Sherman live-trap and 1 museum special (snap trap) placed approximately 1 m apart. All traps were baited with a mixture of peanut butter and oatmeal; the area immediately surrounding each trap was dusted with a carbamate (Sevin) to prevent ants from eating the bait and/or a captured animal.

Traplines were operative for 4 consecutive nights during 4 seasonal trapping periods: spring 1980 (13-17 May); fall 1980 (25-29 October); spring 1981 (21-24 May); and fall 1981 (22-23 October). Traplines were checked daily during operation and the status (sprung-capture, sprung-no capture, or operative) of each trap was recorded. Each captured small mammal was sacrificed, identified to species, weighed (g), sexed, and measured (right ear, right hind foot, tail, and total body length in mm). Also recorded re the date of capture, location of trapline asture, compartment, and habitat type), number trap-station (1-25), and type of trap (Sherman snap) in which each animal was captured. A presentative sample of each species was posited in the Florida State Museum, inesville, Florida.

For each of the 4 trapping periods, the nber of trap-nights per trapline was adjusted to count for traps accidentally sprung by falling aves, rain, or animals that avoided capture. cause these traps may have been operative for me portion of the trapping period, one-half the mber of traps accidentally sprung was subtracted om the number of traps originally set to obtain adjusted trap-night statistic. Subsequently, pture success (%) was calculated for each apline by dividing the total number of dividuals captured by the adjusted number of ap-nights and then multiplying this value by 0. The species richness (number of species ptured), species diversity (H') (Shannon and aver 1949), and biomass (g) of small mammals ptured per trapline were determined also for ch trapping period.

ta Analysis

All data were analyzed by analysis of riance (least squares) procedures (Table 2). e effects of habitat, compartment, season, and ar were tested using the General Linear Models LM) procedure of the Statistical Analysis System (SAS) (Helwig and Council 1979). All statistical tests were performed at a predetermined level of probability ($\underline{P}$=0.05) at the Northeast Regional Data Center, University of Florida, Gainesville, Florida.

Median estimates (i.e., geometric means) reported for log-transformed data (Table 2) were obtained by calculating the antilog of the symetrically-distributed, transformed data; 68% minimum and maximum range values were obtained by calculating the antilog of the mean minus the standard deviation and the antilog of the mean plus the standard deviation of the transformed data, respectively. Similarly, median estimates reported for data subjected to an arcsine-square root transformation were obtained by first squaring the mean of the transformed data, and then calculating the sine of this value; 68% minimum and maximum range values were obtained by squaring the mean minus the standard deviation and the mean plus the standard deviation of the transformed data, and then calculating the sine of these values, respectively (R. C. Littell, pers. commun.).

RESULTS

Birds

A total of 759 birds, representing 53 species, was observed during breeding and wintering censuses in 1980 and 1981 (Table 3, Appendices A. 1-A.3). Irrespective of habitat

Table 2. Parameters and types of transformations used to statistically analyze data collected on bird, herpetofaunal, and small mammal populations, Apalachicola National Forest, Florida, 1980 and 1981.

Population	Parameter	Transformation
Birds[a]	Density (birds/km^2)	log (base 10)
	Species richness (number of species)	log (base 10)
	Species diversity (H')[b]	None
	Biomass (kg)	log (base 10)
Herpetofauna	Number of individuals	log (base 10)
	Species richness (number of species)	log (base 10)
	Species diversity (H')	None
	Biomass (kg)	log (base 10)
Small mammals	Capture success	Arcsine-square root
	Species richness (number of species)	log (base 10)
	Species diversity (H')	None
	Biomass (kg)	log (base 10)

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[a] Assumptions: (1) all birds present within the census strip were observed; (2) detectability of birds was equal between habitat types (natural longleaf and planted slash pine) and between seasons (spring and fall); and (3) detectability and identification of encountered birds were equal among observers.

[b] Shannon-Weiner index of species diversity (Shannon and Weaver 1949).

Table 3. Relative frequency of occurrence of bird species observed during breeding (May) and wintering (December) censuses, Apalachi National Forest, Florida, 1980 and 1981. Data were derived from a strip transect (40 m X 500 m) located in both natural longleaf and planted slash pine habitats in each of the 8 compartments.

Species[a]	% frequency of occurrence								
	Longleaf pine			Slash pine			Subtotal		
	Breeding	Wintering	Subtotal	Breeding	Wintering	Subtotal	Breeding	Wintering	Total
Pine warbler	22 (53)[b]	20 (59)	21(112)	14 (11)	7 (10)	9 (21)	20 (64)	16 (69)	18(133)
Yellow-rumped warbler	0 (0)	14 (42)	8 (42)	0 (0)	27 (39)	17 (39)	0 (0)	19 (81)	11 (81)
Brown-headed nuthatch	14 (35)	5 (14)	9 (49)	13 (10)	0 (0)	4 (10)	14 (45)	3 (14)	8 (59)
American robin	0 (0)	8 (22)	4 (22)	0 (0)	26 (37)	16 (37)	0 (0)	14 (59)	8 (59)
Red-cockaded woodpecker	11 (27)	4 (13)	7 (40)	3 (2)	1 (2)	2 (4)	9 (29)	3 (15)	6 (44)
Sedge wren	0 (0)	11 (32)	6 (32)	0 (0)	6 (9)	4 (9)	0 (0)	9 (41)	5 (41)
Red-bellied woodpecker	7 (17)	<1 (2)	4 (19)	16 (13)	0 (0)	6 (13)	9 (30)	<1 (2)	4 (32)
Bachman's sparrow	9 (23)	2 (6)	5 (29)	1 (1)	<1 (1)	<1 (2)	7 (24)	2 (7)	4 (31)
House wren	0 (0)	7 (19)	4 (19)	0 (0)	8 (11)	5 (11)	0 (0)	7 (30)	4 (30)
Great crested flycatcher	8 (19)	0 (0)	4 (19)	12 (10)	0 (0)	4 (10)	9 (29)	0 (0)	4 (29)
Ruby-crowned kinglet	0 (0)	3 (9)	2 (9)	0 (0)	7 (10)	4 (10)	0 (0)	4 (19)	3 (19)
Chipping sparrow	0 (0)	6 (17)	3 (17)	0 (0)	1 (2)	<1 (2)	0 (0)	4 (19)	3 (19)
White-throated sparrow	0 (0)	6 (18)	3 (18)	0 (0)	0 (0)	0 (0)	0 (0)	4 (18)	2 (18)
Northern bobwhite	6 (14)	0 (0)	3 (14)	0 (0)	0 (0)	0 (0)	4 (14)	0 (0)	2 (14)
Summer tanager	3 (7)	0 (0)	1 (7)	8 (6)	0 (0)	3 (6)	4 (13)	0 (0)	2 (13)
Yellow-bellied sapsucker	0 (0)	3 (9)	2 (9)	0 (0)	<1 (1)	<1 (1)	0 (0)	2 (10)	1 (10)
Blue jay	2 (5)	0 (0)	<1 (5)	5 (4)	0 (0)	2 (4)	3 (9)	0 (0)	1 (9)
American crow	<1 (1)	0 (0)	<1 (1)	9 (7)	<1 (1)	4 (8)	2 (8)	<1 (1)	1 (9)
Eastern bluebird	1 (3)	2 (6)	2 (9)	0 (0)	0 (0)	0 (0)	<1 (3)	1 (6)	1 (9)
Rufous-sided towhee	<1 (2)	<1 (1)	<1 (3)	3 (2)	3 (4)	3 (6)	1 (4)	1 (5)	1 (9)
Red-headed woodpecker	2 (6)	0 (0)	1 (6)	1 (1)	0 (0)	<1 (1)	2 (7)	0 (0)	<1 (7)
Blue-gray gnatcatcher	2 (6)	<1 (1)	1 (7)	0 (0)	0 (0)	0 (0)	2 (6)	<1 (1)	<1 (7)
Eastern phoebe	0 (0)	2 (5)	<1 (5)	0 (0)	<1 (1)	<1 (1)	0 (0)	1 (6)	<1 (6)
Swamp sparrow	0 (0)	2 (6)	1 (6)	0 (0)	0 (0)	0 (0)	0 (0)	1 (6)	<1 (6)
Downy woodpecker	0 (0)	1 (3)	<1 (3)	1 (1)	0 (0)	<1 (1)	<1 (1)	<1 (3)	<1 (4)
Pileated woodpecker	<1 (2)	0 (0)	<1 (2)	3 (2)	0 (0)	<1 (2)	1 (4)	0 (0)	<1 (4)
Eastern wood-pewee	2 (4)	0 (0)	<1 (4)	0 (0)	0 (0)	0 (0)	1 (4)	0 (0)	<1 (4)
Carolina wren	0 (0)	<1 (2)	<1 (2)	1 (1)	<1 (1)	<1 (2)	<1 (1)	<1 (3)	<1 (4)
Solitary vireo	0 (0)	0 (0)	0 (0)	0 (0)	3 (4)	2 (4)	0 (0)	<1 (4)	<1 (4)
Palm warbler	0 (0)	0 (0)	0 (0)	0 (0)	3 (4)	2 (4)	0 (0)	<1 (4)	<1 (4)
Blue grosbeak	2 (4)	0 (0)	<1 (4)	0 (0)	0 (0)	0 (0)	1 (4)	0 (0)	<1 (4)
Eastern kingbird	1 (3)	0 (0)	<1 (3)	0 (0)	0 (0)	0 (0)	<1 (3)	0 (0)	<1 (3)
Fish crow	<1 (2)	0 (0)	<1 (2)	1 (1)	0 (0)	<1 (1)	<1 (3)	0 (0)	<1 (3)
Tufted titmouse	0 (0)	0 (0)	0 (0)	4 (3)	0 (0)	1 (3)	<1 (3)	0 (0)	<1 (3)
Common yellowthroat	0 (0)	<1 (1)	<1 (1)	1 (1)	<1 (1)	<1 (2)	<1 (1)	<1 (2)	<1 (3)
Wood duck	<1 (2)	0 (0)	<1 (2)	0 (0)	0 (0)	0 (0)	<1 (2)	0 (0)	<1 (2)
Wild turkey	<1 (1)	0 (0)	<1 (1)	1 (1)	0 (0)	<1 (1)	<1 (2)	0 (0)	<1 (2)
Hermit thrush	0 (0)	<1 (1)	<1 (1)	0 (0)	<1 (1)	<1 (1)	0 (0)	<1 (2)	<1 (2)
Northern mockingbird	0 (0)	0 (0)	0 (0)	0 (0)	1 (2)	<1 (2)	0 (0)	<1 (2)	<1 (2)
Northern cardinal	<1 (2)	0 (0)	<1 (2)	0 (0)	0 (0)	0 (0)	<1 (2)	0 (0)	<1 (2)
Song sparrow	0 (0)	1 (2)	<1 (2)	0 (0)	0 (0)	0 (0)	0 (0)	<1 (2)	<1 (2)
Common grackle	<1 (1)	0 (0)	<1 (1)	1 (1)	0 (0)	<1 (1)	1 (2)	0 (0)	<1 (2)
Red-shouldered hawk	0 (0)	0 (0)	0 (0)	0 (0)	<1 (1)	<1 (1)	0 (0)	<1 (1)	<1 (1)
Mourning dove	0 (0)	0 (0)	0 (0)	0 (0)	<1 (1)	<1 (1)	0 (0)	<1 (1)	<1 (1)
Yellow-billed cuckoo	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	<1 (1)	<1 (1)	0 (0)	<1 (1)
Barred owl	0 (0)	0 (0)	0 (0)	0 (0)	<1 (1)	<1 (1)	0 (0)	<1 (1)	<1 (1)
Chuck-will's-widow	0 (0)	0 (0)	0 (0)	1 (1)	0 (0)	<1 (1)	<1 (1)	0 (0)	<1 (1)
Hairy woodpecker	0 (0)	<1 (1)	<1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	<1 (1)	<1 (1)
Carolina chickadee	<1 (1)	0 (0)	<1 (1)	0 (0)	0 (0)	0 (0)	<1 (1)	0 (0)	<1 (1)
Brown thrasher	<1 (1)	0 (0)	<1 (1)	0 (0)	0 (0)	0 (0)	<1 (1)	0 (0)	<1 (1)
Northern parula	<1 (1)	0 (0)	<1 (1)	0 (0)	0 (0)	0 (0)	<1 (1)	0 (0)	<1 (1)
Field sparrow	0 (0)	0 (0)	0 (0)	0 (0)	<1 (1)	<1 (1)	0 (0)	<1 (1)	<1 (1)
Orchard oriole	<1 (1)	0 (0)	<1 (1)	0 (0)	0 (0)	0 (0)	<1 (1)	0 (0)	<1 (1)
Total number of birds	100(243)	100(291)	100(534)	100 (80)	100(145)	100(225)	100(323)	100(436)	100(759)
Total number of species	27	24	43	21	23	37	33	32	53

[a] After Eisenmann (1982).

[b] Numbers in parentheses represent number of birds observed.

type, compartment, season, or year, the 5 most frequently observed species were the pine warbler (18%), yellow-rumped warbler (11%), brown-headed nuthatch (8%), American robin (8%), and red-cockaded woodpecker (6%). Twenty-seven (51% of the species observed were year-round residents, 11 (21%) were summer residents, and 15 (28%) were winter residents (Appendix A.1). The density of birds observed -- habitat types, seasons, and years combined, was 118.6 birds/km² (0.5 birds/acre).

Habitats.--Forty-three species of birds, totaling 534 individuals, were observed in natural longleaf pine habitat (Table 3). these, the 5 most frequently observed species the pine warbler (21%), brown-headed nut (9%), yellow-rumped warbler (8%), red-coc woodpecker (7%), and sedge wren (6%). comparison, 37 species, totaling 225 individ were observed in planted slash pine habitat, most common being the yellow- rumped wa (17%), American robin (16%), pine warbler red-bellied woodpecker (6%), and house wren (

Sixteen bird species were observed onl natural longleaf pine, 10 were observed onl planted slash pine, and 27 were observed in bitat types (Table 3). Species observed clusively in longleaf pine were the ite-throated sparrow, northern bobwhite, stern bluebird, blue-gray gnatcatcher, swamp arrow, eastern wood-pewee, blue grosbeak, stern kingbird, wood duck, northern cardinal, ng sparrow, hairy woodpecker, Carolina ickadee, brown thrasher, northern parula, and chard oriole. Species observed exclusively in ash pine were the solitary vireo, palm rbler, tufted titmouse, northern mockingbird, d-shouldered hawk, mourning dove, yellow-billed ckoo, barred owl, chuck-will's widow, and field arrow.

The density of birds observed within atural longleaf pine habitat, seasons and years mbined, was 166.9 birds/km^2 (0.7 birds/acre). e comparable density for planted slash pine abitat was 70.3 birds/km^2 (0.2 birds/acre).

Mean bird density, mean species richness, nd mean species diversity were substantially reater for natural longleaf than planted slash ine during each of the 4 sampling periods Table 4). Differences in mean biomass between abitat types, however, were variable among ampling periods (Table 4).

Because significant ($\underline{P} < 0.05$) habitat-ompartment interactions occurred for both pecies richness and species diversity (Table), further analysis of these parameters with espect to habitat type was precluded. However, o significant ($\underline{P} > 0.05$) habitat interactions ccurred for either bird density or biomass, hereby allowing comparisons of these 2 arameters between habitat types to be made irrespective of compartment, season, or year. These comparisons showed that bird density differed ($\underline{P} < 0.05$) between habitat types, with the estimated median value being greater for natural longleaf than for planted slash pine (Table 6). In contrast, biomass did not differ ($\underline{P} > 0.05$) between the 2 habitat types.

Seasons.--Thirty-three species of birds, totaling 323 individuals, were observed during the breeding season (Table 3); the 5 most frequently observed species were the pine warbler (20%), brown-headed nuthatch (14%), red-bellied woodpecker (9%), red-cockaded woodpecker (9%), and great crested flycatcher (9%). In comparison, 32 species, totaling 436 individuals, were observed during the wintering season, the 5 most common being the yellow-rumped warbler (19%), pine warbler (16%), American robin (14%), sedge wren (9%), and house wren (7%). Twenty bird species were observed only during the breeding season, 21 only during the wintering season, and 12 during both seasons (Table 3). Densities of breeding and wintering birds, habitat types and years combined, were 100.9 birds/km^2 (0.4 birds/acre) and 136.2 birds/km^2 (0.6 birds/acre), respectively.

Significant ($\underline{P} < 0.05$) season-year interactions occurred for each parameter tested -- density, species richness, species diversity, and biomass (Table 5). Consequently, further analyses were restricted to seasonal comparisons within years. These comparisons revealed that bird density differed ($\underline{P} < 0.05$) between seasons in both 1980 and 1981 (Table 7). In 1980, the estimated median value for bird density was greater for wintering than breeding populations, whereas, in 1981, the reverse trend occurred.

Table 4. Density, species richness (number of species), species diversity, and biomass of birds observed per transect within natural longleaf and planted slash pine habitats during breeding (May) and wintering (December) censuses, Apalachicola National Forest, Florida, 1980 and 1981. All means were based on data derived from 8 transects.

	Longleaf pine				Slash pine			
	1980		1981		1980		1981	
Parameter	Breeding	Wintering	Breeding	Wintering	Breeding	Wintering	Breeding	Wintering
Density (birds/km^2)								
Mean	147.5	260.0	156.2	103.8	33.8	141.2	66.2	40.0
SD	63.9	147.4	97.2	186.5	25.6	195.8	40.0	36.2
Species richness								
Mean	6.8	6.9	7.0	3.0	2.1	4.2	3.8	1.6
SD	3.0	2.2	3.5	2.7	1.2	2.8	1.4	0.7
Species diversity (H')								
Mean	1.6	1.5	1.6	0.7	0.7	1.0	1.2	0.3
SD	0.6	0.2	0.5	0.7	0.4	0.7	0.4	0.4
Biomass (kg)								
Mean	1.1	0.6	0.8	0.2	0.2	0.6	1.1	0.1
SD	1.3	0.5	0.7	0.3	0.2	0.8	1.6	0.2

Table 5. Results of analysis of variance procedures for bird population parameters, Apalachicola National Forest, Florida, 1980 and 1981.

		Parameter			
Factor[a]	df	Density ($birds/km^2$)[b]	Species richness (number of species)[b]	Species diversity (H')	Biomass (kg)[b]
H	1	*[c]	*	*	NS
C	7	NS	*	*	NS
H*C	7	NS	*	*	NS
S	1	NS	*	*	*
H*S	1	NS	NS	NS	NS
Y	1	NS	*	*	NS
H*Y	1	NS	NS	NS	NS
S*Y	1	*	*	*	*

[a] H = habitat; C = compartment; S = season; Y = year.

[b] Analysis was executed on log (base 10) transformed data.

[c] Significance of F values: * = $P < 0.05$; NS = $P > 0.05$.

Although species richness, species diversity, and biomass did not differ ($P > 0.05$) between breeding and wintering populations in 1980, they did differ ($P < 0.05$) in 1981 (Table 7). The estimated median values for species richness and biomass were greater for the breeding than the wintering population in 1981. Similarly, the actual mean value for species diversity was greater for the breeding than the wintering population in 1981.

Herpetofauna

A total of 726 amphibians and reptiles, representing 39 species, was captured during spring and fall trapping periods in 1980 and 1981 (Table 8, Appendices B.1-B.3). Irrespective of habitat type, compartment, season, or year, the 5 most frequently captured species were the ground skink (33%), six-lined racerunner (10%), racer (7%), scarlet snake (5%), and smooth earth snak (5%). Twenty-three (59%) of the 39 herpetofauna species captured were terrestrial, 8 (20%) wer semi-aquatic, 4 (10%) were arboreal, 3 (8%) wer aquatic, and 1 (3%) was fossorial (Appendix B.1).

Habitats.--Thirty-five species o herpetofauna, totaling 377 individuals, wer captured in natural longleaf pine habitat (Tabl 8). Of these, the 5 most frequently capture species were the ground skink (27%), six-line racerunner (12%), scarlet snake (8%), racer (5%) and smooth earth snake (4%). In comparison, 3 species, totaling 349 individuals, were capture in planted slash pine habitat, the 5 most commo being the ground skink (40%), racer (8%), six-lined racerunner (7%), green anole (7%), an smooth earth snake (6%).

Table 6. Comparative analysis of bird density and biomass for natural longleaf and planted slash pine habitats, spring and fall censuses combined, Apalachicola National Forest, Florida, 1980 and 1981. All medians were based on data derived from 32 transects.

Parameter	Longleaf pine	Slash pine	F-test[a]
Density ($birds/km^2$)[b]			
Median	108.5	39.2	*
Range (68%)	36.4-319.5	12.0-123.6	
Biomass (kg)[b]			
Median	0.6	0.4	NS
Range (68%)	0.1-1.3	0.0-1.1	

[a] * = $P < 0.05$; NS = $P > 0.05$.

[b] Analysis was executed on log (base 10) transformed data.

Table 7. Comparative analysis of seasonal aspects of bird populations, Apalachicola National Forest, Florida, 1980 and 1981. All medians/means were based on data derived from 16 transects.

	1980			1981		
Parameter	Breeding season	Wintering season	F-test[a]	Breeding season	Wintering season	F-test[a]
Density (birds/km²)[b]						
Median	51.1	124.5	*	81.7	34.8	*
Range (68%)	11.7-212.6	39.2-390.8		34.8-190.3	11.2-103.8	
Species richness (number of species)[b]						
Median	3.5	4.9	NS	4.7	1.9	*
Range (68%)	1.3-7.8	2.5-8.9		2.6-8.2	0.8-3.7	
Species diversity (H')						
Mean	1.2	1.3	NS	1.4	0.5	*
SD	0.7	0.6		0.5	0.6	
Biomass (kg)[b]						
Median	0.5	0.5	NS	0.7	0.2	*
Range (68%)	0.0-1.3	0.1-1.2		0.1-1.8	0.0-0.4	

[a] * = $P < 0.05$; NS = $P > 0.05$.

[b] Analysis was executed on log (base 10) transformed data.

Seven herpetofaunal species were captured only in natural longleaf pine, 4 were captured only in planted slash pine, and 28 were captured in both habitat types (Table 8). Those species captured exclusively in longleaf pine were the oak toad, slender glass lizard, eastern mud turtle, five-lined skink, eastern hognose snake, southern hognose snake, and pine snake. Those species captured exclusively in slash pine were the mole salamander, little grass frog, southern chorus frog, and brown snake.

The mean number of amphibians and reptiles captured per array within natural longleaf pine during the spring of 1980 was nearly twice that captured within planted slash pine (Table 9). Differences in the mean abundance of herpetofauna between habitats during the fall of 1980 and the spring and fall of 1981 were much less pronounced, but favored slash pine. Mean species richness and mean species diversity were greater in longleaf than slash pine during the spring and fall of 1980 and the spring of 1981, whereas the reverse relationship occurred in the fall of 1981 (Table 9). Mean herpetofaunal biomass was greater in longleaf pine during the spring of 1980 and 1981, and greater in slash pine during the fall of 1980 and 1981 (Table 9).

No significant ($P > 0.05$) interaction between habitat and compartment effects, habitat and season effects, or habitat and year effects was determined for any of the parameters tested -- abundance, species richness, species diversity, and biomass (Table 10). As a result, statistical comparisons between natural longleaf and planted slash pine habitats were made irrespective of compartment, season, or year. These comparisons showed that neither the number of individuals captured nor the number of species captured differed ($P > 0.05$) between habitat types; however, the actual mean value for species diversity and the estimated median value for biomass were higher for natural longleaf than planted slash pine (Table 11).

Seasons.--Thirty-six species of herpetofauna, totaling 503 individuals, were captured during the spring (Table 8); the 5 most frequently captured species were the ground skink (35%), six-lined racerunner (12%), scarlet snake (7%), racer (6%), and broadhead skink (5%). In contrast, 33 species, totaling 223 individuals, were captured in fall, the 5 most common being the ground skink (30%), smooth earth snake (10%), racer (8%), green anole (7%), and dwarf salamander (5%).

Six herpetofaunal species were captured only during spring, 3 were captured only during fall, and 30 were captured during both seasons (Table 8). Those species captured exclusively during spring were the eastern mud turtle, mole salamander, southern chorus frog, eastern and southern hognose snake, and brown snake. Those species captured exclusively during fall were the little grass frog, five-lined skink, and pine snake. No significant ($P > 0.05$)

Table 8. Relative frequency of occurrence of herpetofaunal species captured during spring (March-May) and fall (September-October) censuses, Apalachicola National Forest, Florida, 1980 and 1981. Data were derived from a 16-trap array operated in both natural longleaf and planted slash pine habitats in each of the 8 compartments.

	% frequency of occurrence								
	Longleaf pine			Slash pine			Subtotal		
Species[a]	Spring	Fall	Subtotal	Spring	Fall	Subtotal	Spring	Fall	Total
Ground skink	27 (74)[b]	28 (29)	27(103)	44(100)	32 (39)	40(139)	35(174)	30 (68)	33(242)
Six-lined racerunner	15 (41)	6 (6)	12 (47)	9 (20)	2 (3)	7 (23)	12 (61)	4 (9)	10 (70)
Racer	6 (17)	3 (3)	5 (20)	7 (15)	12 (14)	8 (29)	6 (32)	8 (17)	7 (49)
Scarlet snake	11 (31)	<1 (1)	8 (32)	2 (5)	0 (0)	1 (5)	7 (36)	<1 (1)	5 (37)
Smooth earth snake	2 (5)	10 (10)	4 (15)	4 (8)	10 (12)	6 (20)	3 (13)	10 (22)	5 (35)
Green anole	3 (7)	2 (2)	2 (9)	4 (10)	12 (14)	7 (24)	3 (17)	7 (16)	5 (33)
Broadhead skink	5 (15)	<1 (1)	4 (16)	4 (8)	0 (0)	2 (8)	5 (23)	<1 (1)	3 (24)
Eastern narrowmouth toad	3 (8)	7 (7)	4 (15)	2 (5)	2 (3)	2 (8)	3 (13)	4 (10)	3 (23)
Dwarf salamander	1 (4)	5 (5)	2 (9)	2 (5)	5 (6)	3 (11)	2 (9)	5 (11)	3 (20)
Southern leopard frog	3 (8)	7 (7)	4 (15)	<1 (1)	2 (2)	<1 (3)	2 (9)	4 (9)	2 (18)
Southern toad	2 (5)	0 (0)	1 (5)	5 (11)	<1 (1)	3 (12)	3 (16)	<1 (1)	2 (17)
Eastern ribbon snake	1 (4)	0 (0)	1 (4)	4 (9)	2 (2)	3 (11)	3 (13)	<1 (2)	2 (15)
Pigmy rattlesnake	1 (3)	4 (4)	2 (7)	<1 (1)	4 (5)	2 (6)	<1 (4)	4 (9)	2 (13)
Eastern glass lizard	<1 (2)	2 (2)	1 (4)	2 (4)	3 (4)	2 (8)	1 (6)	3 (6)	2 (12)
Eastern coral snake	1 (3)	4 (4)	2 (7)	<1 (2)	2 (3)	1 (5)	<1 (5)	3 (7)	2 (12)
Slimy salamander	3 (8)	<1 (1)	2 (9)	<1 (2)	0 (0)	<1 (2)	2 (10)	<1 (1)	2 (11)
Southeastern five-lined skink	1 (4)	3 (3)	2 (7)	<1 (2)	<1 (1)	<1 (3)	1 (6)	2 (4)	1 (10)
Eastern fence lizard	<1 (2)	4 (4)	2 (6)	1 (3)	<1 (1)	1 (4)	<1 (5)	2 (5)	1 (10)
Common garter snake	2 (6)	0 (0)	2 (6)	1 (3)	<1 (1)	1 (4)	2 (9)	<1 (1)	1 (10)
Flatwoods salamander	<1 (2)	0 (0)	<1 (2)	1 (3)	2 (2)	1 (5)	<1 (5)	<1 (2)	<1 (7)
Oak toad	1 (4)	2 (2)	2 (6)	0 (0)	0 (0)	0 (0)	<1 (4)	<1 (2)	<1 (6)
Corn snake	1 (4)	<1 (1)	1 (5)	<1 (1)	0 (0)	<1 (1)	<1 (5)	<1 (1)	<1 (6)
Ornate chorus frog	<1 (1)	<1 (1)	<1 (2)	<1 (1)	2 (2)	<1 (3)	<1 (2)	1 (3)	<1 (5)
Eastern box turtle	<1 (1)	2 (2)	<1 (3)	<1 (2)	0 (0)	<1 (2)	<1 (3)	<1 (2)	<1 (5)
Slender glass lizard	1 (3)	2 (2)	1 (5)	0 (0)	0 (0)	0 (0)	<1 (3)	<1 (2)	<1 (5)
Southern cricket frog	<1 (1)	<1 (1)	<1 (2)	<1 (1)	<1 (1)	<1 (2)	<1 (2)	<1 (2)	<1 (4)
Eastern mud turtle	1 (4)	0 (0)	1 (4)	0 (0)	0 (0)	0 (0)	<1 (4)	0 (0)	<1 (4)
Coachwhip	1 (3)	0 (0)	<1 (3)	0 (0)	<1 (1)	<1 (1)	<1 (3)	<1 (1)	<1 (4)
Ringneck snake	<1 (1)	<1 (1)	<1 (2)	0 (0)	<1 (1)	<1 (1)	<1 (1)	<1 (2)	<1 (3)
Scarlet kingsnake	<1 (1)	0 (0)	<1 (1)	<1 (1)	<1 (1)	<1 (2)	<1 (2)	<1 (1)	<1 (3)
Glossy crayfish snake	<1 (1)	<1 (1)	<1 (2)	<1 (1)	0 (0)	<1 (1)	<1 (2)	<1 (1)	<1 (3)
Mole salamander	0 (0)	0 (0)	0 (0)	<1 (2)	0 (0)	<1 (2)	<1 (2)	0 (0)	<1 (2)
Little grass frog	0 (0)	0 (0)	0 (0)	0 (0)	2 (2)	<1 (2)	0 (0)	<1 (2)	<1 (2)
Southern chorus frog	0 (0)	0 (0)	0 (0)	<1 (1)	0 (0)	<1 (1)	<1 (1)	0 (0)	<1 (1)
Five-lined skink	0 (0)	<1 (1)	<1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	<1 (1)	<1 (1)
Eastern hognose snake	<1 (1)	0 (0)	<1 (1)	0 (0)	0 (0)	0 (0)	<1 (1)	0 (0)	<1 (1)
Southern hognose snake	<1 (1)	0 (0)	<1 (1)	0 (0)	0 (0)	0 (0)	<1 (1)	0 (0)	<1 (1)
Pine snake	0 (0)	<1 (1)	<1 (1)	0 (0)	0 (0)	0 (0)	0 (0)	<1 (1)	<1 (1)
Brown snake	0 (0)	0 (0)	0 (0)	<1 (1)	0 (0)	<1 (1)	<1 (1)	0 (0)	<1 (1)
Total number of amphibians and reptiles	100(275)	100(102)	100(377)	100(228)	100(121)	100(349)	100(503)	100(223)	100(726)
Total number of species	33	26	35	29	23	32	36	33	39

[a] After Collins et al. (1982).

[b] Numbers in parentheses represent number of amphibians and reptiles captured.

season-habitat interactions occurred for any of the 4 parameters tested. A significant ($P < 0.05$) interaction did occur, however, between season and year with respect to the number of individuals captured. Although this interaction was not significant ($P > 0.05$) for other parameters tested, 2 separate sets of statistical comparisons, 1 for each year of the study, were made in order to maintain consistency in data analysis. These comparisons showed that the abundance, species richness, and biomass of captured herpetofauna differed ($P < 0.05$) between seasons in both 1980 and 1981 (Table 12), with the estimated median value for each of these parameters being greater for spring than fall in both years. Species diversity differed ($P < 0.05$) between seasons in 1980, but not ($P > 0.05$) in 1981. Yet, in both years, the value for actual mean species diversity was greater for spring than fall.

Small Mammals

A total of 198 small mammals, representing 5 species, was captured during spring and fall 1980 and 1981 (Table 13, Appendices C.1 and C.2 The species composition of the sample was: cott mouse, 47%; cotton rat, 44%; least shrew, 8 southern short-tailed shrew, 1%; and house mous 1%.

A steady decline in capture success occurr during the 2-year study period, with captu success being greatest in the spring of 19 (3.4%) and least in the fall of 1981 (0.6 (Appendices C.1 and C.2). Total capture succe for the area, habitats, seasons, and yea combined, was 1.6%.

Habitats.--Four species of small mammal totaling 106 individuals, were captured in natur longleaf pine habitat (Table 13). The cotton r was the most frequently captured (47%) specie In comparison, 4 species, totaling 92 individual were captured in planted slash pine habitat, wi the cotton mouse being the most frequent captured (51%) species. The house mouse w captured only in natural longleaf pine, where

Table 9. Abundance, species richness (number of species), species diversity, and biomass of herpetofauna captured per array within natural longleaf and planted slash pine habitats during spring (March-May) and fall (September-October) censuses, Apalachicola National Forest, Florida, 1980 and 1981. All means were based on data derived from 8 arrays.

	Longleaf pine				Slash pine			
	1980		1981		1980		1981	
Parameter	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
Number of individuals								
Mean	16.4	6.6	18.0	6.1	9.4	8.8	19.1	6.4
SD	7.5	2.1	6.1	3.8	4.8	8.0	9.1	4.7
Species richness								
Mean	7.5	4.6	7.8	3.4	5.4	4.0	5.2	3.9
SD	3.2	1.7	1.7	1.8	2.4	2.3	1.7	2.3
Species diversity (H')								
Mean	1.6	1.3	1.6	0.9	1.4	1.0	1.0	1.2
SD	0.5	0.5	0.2	0.6	0.6	0.7	0.3	0.5
Biomass (g)								
Mean	351.8	64.8	403.5	126.8	110.5	137.4	180.5	138.9
SD	320.2	107.6	244.6	237.9	92.3	231.4	125.4	231.8

e southern short-tailed shrew was captured only planted slash pine. Capture success in natural ngleaf pine and planted slash pine, seasons and ars combined, was 1.8% and 1.5%, respectively.

Mean capture success and mean biomass of all mammals were greater in natural longleaf an planted slash pine during spring and greater planted slash pine than natural longleaf pine ring fall of both 1980 and 1981 (Table 14). an species richness and mean species diversity re greater in longleaf than slash during the fall of 1980 and the spring of 1981 (Table 14); the reverse relationship occurred during the spring of 1980 and the fall of 1981.

Because a significant ($P < 0.05$) habitat-compartment interaction occurred for species richness (Table 15), further statistical analysis of this parameter was precluded. No significant ($P > 0.05$) habitat interactions occurred, however, for capture success, species diversity, or biomass. Thus, habitat comparisons of these 3 parameters were made irrespective of

Table 10. Results of analysis of variance procedures for herpetofaunal population parameters, Apalachicola National Forest, Florida, 1980 and 1981.

Factor[a]	df	Number of individuals[b]	Species richness (number of species)[b]	Species diversity (H')	Biomass (g)[b]
H	1	NS[c]	NS	*	*
C	7	NS	*	*	NS
H*C	7	NS	NS	NS	NS
S	1	*	*	*	*
H*S	1	NS	NS	NS	NS
Y	1	NS	NS	NS	NS
H*Y	1	NS	NS	NS	NS
S*Y	1	*	NS	NS	NS

[a] H = habitat; C = compartment; S = season; Y = year

[b] Analysis was executed on log (base 10) transformed data.

[c] Significance of F values: * = $P < 0.05$; NS = $P > 0.05$.

Table 11. Comparative analysis of herpetofaunal abundance, species richness (number of species), species diversity, and biomass for natural longleaf and planted slash pine habitats, spring and fall censuses combined, Apalachicola National Forest, Florida, 1980 and 1981. All medians/means were based on data derived from 32 transects.

Parameter	Longleaf pine	Slash pine	F-test[a]
Number of individuals [b]			
Median	9.5	8.2	NS
Range (68%)	4.4-19.8	3.2-19.0	
Species richness[b]			
Median	5.2	4.1	NS
Range (68%)	2.9-9.0	2.2-7.2	
Species diversity (H')			
Mean	1.4	1.1	*
SD	0.6	0.5	
Biomass (g)[b]			
Median	99.7	65.2	*
Range (68%)	21.4-451.4	14.5-281.1	

[a] * = *P* < 0.05; NS = *P* > 0.05.

[b] Analysis was executed on log (base 10) transformed data.

Table 12. Comparative analysis of seasonal aspects of herpetofaunal populations, Apalachicola National Forest, Florida, 1980 and 1981. All medians/means were based on data derived from 16 transects.

	1980			1981		
Parameter	Spring	Fall	F-test[a]	Spring	Fall	F-test[a]
Number of individuals						
Median	10.8	6.3	*	17.1	5.0	*
Range (68%)	5.2-21.7	3.0-12.5		10.8-26.8	2.1-10.7	
Species richness (number of species)[b]						
Median	5.9	3.9	*	6.2	3.2	*
Range (68%)	3.2-10.1	2.2-6.6		4.3-8.9	1.7-5.6	
Species diversity (H')[c]						
Mean	1.5	1.1	*	1.3	1.0	NS
SD	0.6	0.6		0.4	0.6	
Biomass (g)[b]						
Median	134.3	32.9	*	189.0	50.0	*
Range (68%)	45.9-389.6	5.8-168.6		54.0-656.2	12.1-197.3	

[a] * = *P* < 0.05; NS = *P* > 0.05.

[b] Analysis was executed on log (base 10) transformed data.

Table 13. Relative frequency of occurrence of small mammal species captured during spring (May) and fall (October) censuses, Apalachicola National Forest, Florida, 1980 and 1981. Data were derived from a 375-m, 25-station transect, with 1 live trap and 1 snap trap per station, operated in both natural longleaf and planted slash pine habitats in each of the 8 compartments.

	% frequency of occurrence								
	Longleaf pine			Slash pine			Subtotal		
Species[a]	Spring	Fall	Subtotal	Spring	Fall	Subtotal	Spring	Fall	Total
Cotton mouse	38 (29)[b]	57 (17)	43 (46)	56 (31)	43 (16)	51 (47)	46 (60)	49 (33)	47 (93)
Cotton rat	56 (42)	27 (8)	47 (50)	38 (21)	43 (16)	40 (37)	48 (63)	36 (24)	44 (87)
Least shrew	5 (4)	16 (5)	9 (9)	6 (3)	11 (4)	8 (7)	5 (7)	13 (9)	8 (16)
Southern short-tailed shrew	0 (0)	0 (0)	0 (0)	0 (0)	3 (1)	1 (1)	0 (0)	2 (1)	< 1 (1)
House mouse	1 (1)	0 (0)	< 1 (1)	0 (0)	0 (0)	0 (0)	< 1 (1)	0 (0)	< 1 (1)
Total number of small mammals	100 (76)	100 (30)	100(106)	100 (55)	100 (37)	100 (92)	100(131)	100 (67)	100(198)
Total number of species	4	3	4	3	4	4	4	4	5

[a] After Jones et al. (1982).

[b] Numbers in parentheses represent number of small mammals captured.

compartment, season, or year. These comparisons showed that neither capture success, species diversity, nor biomass differed (P > 0.05) between natural longleaf and planted slash pine habitat types (Table 16).

Seasons.--Four species of small mammals, totaling 131 individuals, were captured during spring; the cotton rat was the most frequently captured (48%) species. In comparison, 4 species, totaling 67 individuals, were captured during fall, with the cotton mouse being the most frequently captured (49%) species. The house mouse was captured only during spring, whereas the southern short-tailed shrew was captured only during fall. Spring capture success was 2.1%; fall capture success was 1.1%.

No significant (P > 0.05) interactions occurred between season and habitat or between season and year for any population parameter (Table 15). Consequently, statistical comparisons between spring and fall were made irrespective of habitat or year. These comparisons showed that each of the 4 parameters -- capture success, species richness, species

Table 14. Capture success, species richness, species diversity, and biomass of small mammals trapped per transect within natural longleaf and planted slash pine habitats during spring (May) and fall (October) censuses, Apalachicola National Forest, Florida, 1980 and 1981. All means were based on data derived from 8 transects.

	Longleaf pine				Slash pine			
	1980		1981		1980		1981	
Parameter	Spring	Fall	Spring	Fall	Spring	Fall	Spring	Fall
Capture success (%)								
Mean	3.8	1.5	1.3	0.5	3.1	1.8	0.5	0.7
SD	3.6	1.4	1.2	0.4	2.1	1.7	0.5	0.7
Species richness (number of species)								
Mean	1.6	1.2	1.5	0.8	1.9	1.1	0.8	0.9
SD	1.1	0.9	1.2	0.5	1.1	1.0	0.7	0.8
Species diversity (H')								
Mean	0.4	0.2	0.3	0.0	0.6	0.1	0.1	0.3
SD	0.4	0.3	0.4		0.4	0.1	0.3	0.4
Biomass (g)								
Mean	423.0	117.5	130.2	31.4	264.1	192.8	70.8	38.4
SD	428.2	77.4	151.9	37.9	188.0	265.5	78.6	43.0

Table 15. Results of analysis of variance procedures for small mammal population parameters, Apalachicola National Forest, Florida, 1980 and 1981.

Factor[a]	df	Capture success (%)[b]	Species richness (number of species)[c]	Species diversity (H')	Biomass (g)[c]
H	1	NS[d]	NS	NS	NS
C	7	*	*	NS	*
H*C	7	NS	*	NS	NS
S	1	*	*	*	*
H*S	1	NS	NS	NS	NS
Y	1	*	*	*	*
H*Y	1	NS	NS	NS	NS
S*Y	1	NS	NS	NS	NS

[a] H = habitat; C = compartment; S = season; Y = year.

[b] Analysis was executed on arcsine-square root transformed data.

[c] Analysis was executed on log (base 10) transformed data.

[d] Significance of F values: * = $\underline{P} < 0.05$; NS = $\underline{P} > 0.05$.

diversity, and biomass -- differed ($\underline{P} < 0.05$) between seasons (Table 17). Estimated median values for capture success, species richness, and biomass were greater for spring than fall. Similarly, the actual mean value for species diversity was greater for spring than fall.

DISCUSSION

Birds

In general, there is a paucity of information regarding year-round bird populations in longleaf and slash pine habitats. Most studies
concentrated on breeding (Johnston and Odum 1
Dickson et al. 1980) or wintering populat
(Emlen 1978, Engstrom and James 1981), but ra
on both (Repenning and Labisky 1985). The t
of 53 species recorded on the Apalachi
National Forest in this study, however,
comparable to year-round species accounts repo
for similar pine habitats in Florida: 49 spe
(Hirth and Marion 1979), 53 species-- also on
Apalachicola National Forest (Repenning
Labisky 1985), 69 species (Engstrom 1980a, 198
and 78 species (Rowse 1980). Thus, pine habi

Table 16. Comparative analysis of small mammal capture success, species diversity, and biomass for natural longleaf and planted slash pine habitats, spring and fall censuses combined, Apalachicola National Forest, Florida, 1980 and 1981. All medians were based on data derived from 32 transects; the means for H' were based on data from 27 and 23 transects in longleaf and slash pine, respectively.

Parameter	Longleaf pine	Slash pine	F-tests[a]
Capture success (%)[b]			
Median	1.4	1.2	NS
Range (68%)	0.2-3.5	0.2-3.0	
Species diversity (H')			
Mean	0.2	0.3	NS
SD	0.4	0.3	
Biomass (g)[c]			
Median	46.9	32.2	NS
Range (68%)	4.8-394.2	2.1-355.4	

[a] * = $\underline{P} < 0.05$; NS = $\underline{P} > 0.05$.

[b] Analysis was executed on arcsine-square root transformed data.

[c] Analysis was executed on log (base 10) transformed data.

Table 17. Comparative analysis of seasonal aspects of small mammal populations, Apalachicola National Forest, Florida, 1980 and 1981. All medians were based on data derived from 32 transects; the means for H' were based on data from 26 and 24 transects in spring and fall, respectively.

Parameter	Spring	Fall	F-tests[a]
Capture success (%)[b]			
Median	1.7	0.9	*
Range (68%)	0.3-4.3	0.2-2.2	
Species richness (number of species)[c]			
Median	1.2	0.8	*
Range (68%)	0.4-2.5	0.2-1.8	
Species diversity (H')			
Mean	0.4	0.1	*
SD	0.4	0.2	
Biomass (g)[c]			
Median	62.1	24.2	*
Range (68%)	5.5-610.8	2.0-212.4	

Florida support a relatively diverse group of rd species on an annual basis.

Habitats.--Bird density differed ($P < 0.05$) etween habitat types on the Apalachicola National orest, with more birds being observed in natural ongleaf than in planted slash pine stands. The ifferential avian use of the 2 pine habitats is robably attributable to differences in vegetative tructure and/or stand age. Harris et al. (1975) nd Repenning and Labisky (1985) found that the bundance, species richness, and species diversity f birds in north Florida were greater in mature atural stands of longleaf pine than in younger tands of planted slash pine, the differences eing due to the higher degree of structural iversity exhibited by the longleaf stands. imilarly, Noble and Hamilton (1976) concluded hat mature natural pine stands in southeastern ouisiana supported more numbers and species of irds than younger loblolly pine (*P. taeda*) lantations because the older stands had a more bundant and diversified vegetative strata. lthough the vegetation within the pine habitats ensused on the Apalachicola National Forest was ot evaluated empirically, natural longleaf stands ppeared structurally more diverse than planted lash pine stands. Not only were stands of atural longleaf greater in age than those of lanted slash pine, but they seemed also to offer set of vegetative features not available in the ounger slash pine stands (e.g., snags, thick round cover, and an open canopy). Thus, mature atural stands of longleaf, due to their tructural diversity, are seemingly capable of upporting a greater abundance of birds than ounger stands of planted slash pine.

Seasons.--Wintering bird populations in the southeastern United States typically are larger than breeding bird populations (Noble and Hamilton 1976, Ortego et al. 1978, Dickson and Noble 1978, Harris 1980, Rowse 1980, Repenning and Labisky 1985). Findings from the Apalachicola National Forest supported this generalization in 1980, when the density of wintering birds exceeded that of breeding birds. In 1981, however, the trend was reversed, as the density of breeding birds exceeded that of wintering birds. This between-year inconsistency in seasonal bird populations on the Apalachicola National Forest was due primarily to the scarcity and/or absence of several common winter migrants in 1981 (e.g., American robin, ruby-crowned kinglet, sedge wren, and house wren). Notably, low populations of wintering birds were reported throughout Florida in 1981 (Stevenson 1982). The relatively low density, species richness, species diversity, and biomass of birds recorded during the winter of 1981 was very likely related to a reduced availability of food resources. Rainfall was markedly below average throughout the spring, summer, and fall of 1981, resulting in severe drought conditions throughout Florida. This drought condition undoubtedly depressed fruit and seed production, thereby reducing the potential food supply for the contingent of birds that normally winter in Florida. Findings for the Apalachicola National Forest strongly suggest that mature stands of natural longleaf pine represent an important habitat for breeding and wintering bird populations. Consequently, maintenance of the current avifaunal community in north Florida will be dependent, in part, on the future availability of natural stands of longleaf pine.

Herpetofauna

The catalog of herpetofaunal species presented for the Apalachicola National Forest does not constitute a complete inventory of all amphibians and reptiles occurring in the Apalachicola River drainage basin. Means (1977) reported that the Apalachicola basin supported at least 108 herpetofaunal species; only 39 species were recorded in this study. One possible explanation for the reduced number of herpetofaunal species captured on the Apalachicola National Forest centers on the drift-fence/funnel-trap array system utilized in the study. The technique has an inherent bias in that it tends to select for small, ground-dwelling animals (Campbell and Christman 1977). Other animals, such as large snakes or turtles, will not fit in the traps, and, consequently, are not captured. Arboreal species, although captured occasionally, also are selected against. Furthermore, because the arrays were not located near creeks, cypress ponds, or other areas of standing water, many aquatic species were not represented. Nonetheless, standardized drift-fence trapping systems have been proven effective in providing data on relative abundance and diversity of herpetofaunal communities (Gibbons and Semlitsch 1981, Campbell and Christman 1977).

Habitats.--It is axiomatic, within certain limitations, that a positive correlation exists between the diversity of habitat and the diversity of vertebrate fauna. Yet, despite the homogeneity often associated with southeastern pine-flatwood monocultures (Williams 1972), findings for the Apalachicola National Forest indicated that longleaf and slash pine habitats are capable of supporting a relatively high diversity of herpetofauna (39 species) when compared with seemingly more diverse habitats within Florida. For example, Campbell and Christman (1977), operating drift-fence arrays in 18 different habitat types, collected 43 species of reptiles and amphibians. Similarly, using drift-fence arrays in north Florida, White (1983) found 29 species of herpetofauna along a slash pine/meadow ecotone, Vickers et al. (1985) reported 38 species from diverse cypress pond/flatwood habitats, and Enge and Marion (1986) captured 45 species on a pine flatwoods site. The relatively high species richness found in pine habitats on the Apalachicola National Forest probably was due to between-stand heterogeneity, as substantial differences in habitat components such as stand age, soil type, canopy closure, stand density, and ground cover structure and composition occurred among the 16 herpetofaunal trapping sites.

Neither the abundance nor species richness of herpetofauna on the Apalachicola National Forest differed ($\underline{P} > 0.05$) between natural longleaf and planted slash pine habitat types, which suggested that pine-type had little influence on the species composition and distribution of herpetofaunal communities. Caution must be exercised, however, when making such a broad generalization about such a diverse and complex group of animals. Although habitats are generally defined and characterized by major vegetative components, microhabitats dominant role in determining the presence abundance, of herpetofauna (Kiester 1971, and Colwell 1977). An increase in ground structural diversity (e.g., fallen logs branches, stumps, rocks) provides a g number of available microhabitats for wi (Maser et al. 1979), and partitioning of available microhabitats permits the coexi of a greater number of species. Therefore attempt to determine the suitability of a area to herpetofauna should include assessment of available microhabitats, su ground-level diversity, litter depth composition, and proximity to aquatic Consequently, the inference that herpeto communities do not differ between na longleaf and planted slash pine habitats m premature, inasmuch as variables affe microhabitat diversity were not consider this study. Clearly, a research design th sensitive to "fine-grained" habitat variabl needed to evaluate the relative value of lo and slash pine habitats to herpetofauna.

Seasons.--The number of amphibians reptiles captured on the Apalachicola Nat Forest differed ($\underline{P} < 0.05$) between seasons i 1980 and 1981, the abundance of herpetofauna greater during spring than fall. Give ectothermic physiology of these animals, seasonal fluctuations in herpetofaunal popul are not surprising. Other studies have show the abundance, distribution, dispersal, breeding activity of various herpetofaunal s is influenced frequently by climate-re environmental factors such as temperature rainfall (Bider 1968, Gibbons and Bennett Wygoda 1979). The relatively high numbe amphibians and reptiles captured during s probably was due to a favorable set of cli conditions (i.e., above-average rainfall moderate temperatures), which caused an inc in daily movements and/or population abund Conversely, the relatively low number individuals captured during the fall was pr the result of a less favorable set of cli conditions (i.e., below-average rainfall elevated temperatures), which diminished movements and/or population abundance.

This study suggests that herpetof populations on the Apalachicola National F may be governed as much by weather factors habitat type. Preliminarily, however, lon pine appears to support a more divers community of herpetofauna, and, there warrants further consideration in assessin habitat requirements.

Small Mammals

Means (1977) listed 16 species terrrestrial small mammals as occurring i Apalachicola River drainage basin. That only these species were captured during this probably was due, at least in part, to the that trapping was limited to longleaf and pine habitats. Pine habitats are intermedia ecies richness of small mammals when compared th other Florida habitat types (Layne 1974, orida Game and Fresh Water Fish Commission 76). More species of small mammals likely would ve been captured had additional habitat types, ch as titi thickets, cypress swamps, or upland rdwoods, been sampled.

Nonetheless, the species composition and ecies richness of small mammals captured on the alachicola National Forest were comparable to ose reported for similar pine habitats through- t Florida. As in this study, the cotton mouse d cotton rat generally were the 2 most common ne-inhabiting species, whereas the total number species captured in pinelands typically ranged om 1 to 5 (Layne 1974, Florida Fresh Water Fish d Game Commission 1976).

Small mammal capture success rates reported r pine habitats throughout Florida reflect nsiderable variation -- 0.1% (U.S. Fish and ldlife Service 1978); 1.4% (Harris et al. 1975); 6% (this study); 2.3% (Layne 1974); and 3.2% lorida Game and Fresh Water Fish Commission 76). The low capture success in this study was obably related to severe drought conditions that curred during the spring, summer, and fall of 81. Other studies have shown that lack of infall, by reducing the quantity and quality of ailable forage plants, adversely affects small mmal populations (Layne 1974). As a result, the productive effort of breeding-age adults often lowered, which subsequently causes a decline in pulation abundance (McCarley 1954, Odum 1955). e steady decrease in capture success observed in is study followed this drought-related pattern, d thereby, further substantiated that a close lationship exists between climatic conditions d the dynamics of small mammal populations.

Habitats.--Findings for the Apalachicola tional Forest revealed that small mammal capture ccess did not differ ($P > 0.05$) between natural ngleaf and planted slash pine habitat types. mparable studies conducted in Florida, however, ve indicated that capture rates were nsiderably lower in slash pine plantations than natural longleaf pine stands (Harris et al. 975, Florida Game and Fresh Water Fish Commission 976). These varying findings may have been due habitat differences other than pine type. merous researchers have found that the stribution and abundance of small mammal pulations are governed, to a large extent, by e structure of understory and ground-level getation (Dambach 1944, Pearson 1959, Shure 970, Layne 1974, M'Closkey 1975, M'Closkey and ajoie 1975, Hanley and Page 1982). Consequently, sessing the differences in "microhabitats" d/or forest management practices that affect ese microhabitats, such as site preparation Umber and Harris 1975, Harris et al. 1975, White al. 1976) or prescribed burning (Arata 1959, ayne 1974), may be more relevant considerations en comparing small mammal populations between bitat types than overstory species composition.

Seasons.--Capture success differed ($P < 0.05$) etween seasons on the Apalachicola National Forest; small mammals were more abundant during spring than fall. This seasonal difference was principally the result of fluctuations in cotton mouse and cotton rat populations, inasmuch as these 2 species accounted for 91% of all small mammals captured on the study area. Substantially more cotton mice and cotton rats were captured during the spring (60 and 63, respectively) than the fall (33 and 24, respectively). Comparable studies have shown that cotton mouse populations typically are larger during spring than fall (Pournelle 1952, McCarley 1954). In contrast, cotton rat abundance generally has been found to be lower during spring than fall (Odum 1955). Yet, as previously mentioned, the drought that occurred during 1981 probably affected the normal breeding behavior of small mammals on the study area, and thereby may have caused the low abundance of cotton rats in fall.

In summary, pine-type, at least in the years of this study, appeared to influence the abundance and species composition of spring and fall populations of small mammals less than did weather. These findings give rise to the speculation that, given a favorable set of climatic conditions, both natural longleaf and planted slash pine habitats on the Apalachicola National Forest might be capable of supporting a greater abundance of small mammals than observed in this study.

ASSESSMENT

The comparative inventory statistics for birds, herpetofauna, and small mammals in longleaf pine and slash pine habitats on the Apalachicola National Forest revealed that abundance, species richness, species diversity, and biomass for the 3 groups (with the exception of species diversity of small mammals) tended to be greater in longleaf pine than in planted slash pine. Additionally, Repenning and Labisky (1985) documented that planted slash pine in north Florida does not provide habitat suitable for maintaining the breeding bird community of natural longleaf pine forest. Collectively, these data suggest that longleaf pine is a critically important wildlife habitat in Florida. Notably, however, the acreage of longleaf pine forest in Florida was decreased by 84% in the three decades between 1950 and 1980 (McCormick 1950, Bechtold and Knight 1982), which evinces a critical reduction in prime pineland habitat for many vertebrate wildlife species. Thus, efforts not only to maintain but also to increase the current acreage of longleaf pine forest constitute an appropriate strategy for enhancing vertebrate wildlife resources in Florida.

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Appendix A.1. Common name, scientific name, abundance status, and body weight for bird species observed within census transects, Apalachicola National Forest, Florida, 1980 and 1981.

Common name[a]	Scientific name[a]	Abundance status[b]	Body weight (g)	Body weight reference[c]
American robin	*Turdus migratorius*	C	74.87	1
Barred owl	*Strix varia*	A	510.00	2
Blue-gray gnatcatcher	*Polioptila caerulea*	B	5.87	4
Blue grosbeak	*Guiraca caerulea*	B	27.18	4
Blue jay	*Cyanocitta cristata*	A	90.00	3
Brown-headed nuthatch	*Sitta pusilla*	A	9.93	4
Brown thrasher	*Toxostoma rufum*	A	66.00	1
Carolina chickadee	*Parus carolinensis*	A	9.01	4
Chuck-will's widow	*Caprimulgus carolinensis*	B	119.60	7
Common grackle	*Quiscalus quiscula*	A	103.52	8
Common yellowthroat	*Geothlypis trichas*	A	11.85	5
Crow, American	*Corvus brachyrhynchos*	A	482.75	1
Crow, fish	*Corvus ossifragus*	A	273.50	2
Eastern bluebird	*Sialia sialis*	B	32.55	3
Eastern kingbird	*Tyrannus tyrannus*	B	38.50	3
Eastern phoebe	*Sayornis phoebe*	C	20.00	1
Eastern wood-peewee	*Contopus virens*	B	13.82	4
Great crested flycatcher	*Myiarchus crinitus*	B	33.09	4
Hermit thrush	*Catharus guttatus*	C	29.50	2
Mourning dove	*Zenaida macroura*	A	130.00	2
Northern bobwhite	*Colinus virginianus*	A	186.77	1
Northern cardinal	*Cardinalis cardinalis*	A	42.37	1
Northern mockingbird	*Mimus polyglottos*	A	49.33	4
Northern parula	*Parula americana*	B	11.85	2
Orchard oriole	*Icterus spurius*	B	23.00	2
Red-shouldered hawk	*Buteo lineatus*	A	804.00	2
Ruby-crowned kinglet	*Regulus calendula*	C	6.73	2
Rufous-sided towhee	*Pipilo erythrophthalmus*	A	41.75	1
Solitary vireo	*Vireo solitarius*	C	16.75	2
Sparrow, Bachman's	*Aimophila aestivalis*	A	18.34	4
Sparrow, chipping	*Spizella passerina*	C	13.50	2
Sparrow, field	*Spizella pusilla*	C	12.10	2
Sparrow, song	*Melospiza melodia*	C	20.70	3
Sparrow, swamp	*Melospiza georgiana*	C	17.00	2
Sparrow, white-throated	*Zonotrichia albicollis*	C	27.50	3

Appendix A.1. Continued

Common name[a]	Scientific name[a]	Abundance status[b]	Body weight (g)	Body weight reference[c]
Summer tanager	Piranga rubra	B	29.53	4
Tufted titmouse	Parus bicolor	A	22.50	2
Warbler, palm	Dendroica palmarum	C	10.20	5
Warbler, pine	Dendroica pinus	A	11.90	1
Warbler, yellow-rumped	Dendroica coronata	C	15.50	2
Wild turkey	Meleagris gallopavo	A	3897.00	2
Wood duck	Aix sponsa	A	658.00	6
Woodpecker, downy	Picoides pubescens	A	26.75	1
Woodpecker, hairy	Picoides villosus	A	72.00	1
Woodpecker, pileated	Dryocopus pileatus	A	260.77	2
Woodpecker, red-bellied	Melanerpes carolinus	A	67.50	1
Woodpecker, red-cockaded	Picoides borealis	A	43.50	4
Woodpecker, red-headed	Melanerpes erythrocephalus	A	68.50	1
Wren, Carolina	Thryothorus ludovicianus	A	18.67	4
Wren, house	Troglodytes aedon	C	11.00	2
Wren, sedge	Cistothorus platensis	C	8.30	5
Yellow-bellied sapsucker	Sphyrapicus varius	C	51.15	8
Yellow-billed cuckoo	Coccyzus americanus	B	61.00	2

[a] After Eisenmann (1982).

[b] Status: A = year-round resident; B = summer resident; C = winter resident.

[c] References: 1 = Stewart (1937); 2 = Poole (1938); 3 = Stegeman (1955); 4 = Norris and Johnston (1958); 5 = Graber and Graber (1962); 6 = Palmer (1976); 7 = Rohwer and Butler (1977); 8 = Clench and Leberman (1978).

ppendix A.2. Number (N) and density (birds/km^2) f birds observed during breeding season (May) ensuses, Apalachicola National Forest, Florida, 980 and 1981. Data were derived from a strip ransect (40 m x 500 m; 131 ft x 1,640 ft) located n both natural longleaf and planted slash pine abitats in each of the 8 compartments; each ransect was censused 5 times.

	Longleaf pine		Slash pine	
Species	1980	1981	1980	1981
Blue-gray gnatcatcher				
N	2	4	0	0
Density	2.5	5.0		
Blue grosbeak				
N	0	4	0	0
Density		5.0		
Blue jay				
N	1	4	0	4
Density	1.2	5.0		5.0
Brown-headed nuthatch				
N	5	30	0	10
Density	6.2	37.5		12.5
Brown thrasher				
N	1	0	0	0
Density	1.2			
Carolina chickadee				
N	1	0	0	0
Density	1.2			

Appendix A.2. Continued.

	Longleaf pine		Slash pine	
Species	1980	1981	1980	1981
Chuck-will's widow				
N	0	0	0	1
Density				1.2
Common grackle				
N	1	0	1	0
Density	1.2		1.2	
Common yellowthroat				
N	0	0	0	1
Density				1.2
Crow, American				
N	0	1	2	5
Density		1.2	2.5	6.2
Crow, fish				
N	0	2	0	1
Density		2.5		1.2
Eastern bluebird				
N	2	1	0	0
Density	2.5	1.2		
Eastern kingbird				
N	1	2	0	0
Density	1.2	2.5		
Eastern wood-peewee				
N	1	3	0	0
Density	1.2	3.8		

Appendix A.2. Continued.

	Longleaf pine		Slash pine	
Species	1980	1981	1980	1981
Great crested flycatcher				
N	9	10	5	5
Density	11.2	12.5	6.2	6.2
Northern bobwhite				
N	9	5	0	0
Density	11.2	6.2		
Northern cardinal				
N	2	0	0	0
Density	2.5			
Northern parula				
N	1	0	0	0
Density	1.2			
Orchard oriole				
N	0	1	0	0
Density		1.2		
Rufous-sided towhee				
N	2	0	0	2
Density	2.5			2.5
Sparrow, Bachman's				
N	9	14	0	1
Density	11.2	17.5		1.2
Summer tanager				
N	0	7	3	3
Density		8.8	3.8	3.8
Tufted titmouse				
N	0	0	2	1
Density			2.5	1.2
Warbler, pine				
N	40	13	9	2
Density	25.0	16.2	11.2	2.5
Wild turkey				
N	1	0	0	1
Density	1.2			1.2
Wood duck				
N	0	2	0	0
Density		2.5		
Woodpecker, downy				
N	0	0	1	0
Density			1.2	
Woodpecker, pileated				
N	1	1	0	2
Density	1.2	1.2		2.5
Woodpecker, red-bellied				
N	8	9	3	10
Density	10.0	11.2	3.8	12.5
Woodpecker, red-cockaded				
N	20	7	0	2
Density	25.0	8.8		2.5
Woodpecker, red-headed				
N	1	5	0	1
Density	1.2	6.2		1.2
Wren, Carolina				
N	0	0	1	0
Density			1.2	
Yellow-billed cuckoo				
N	0	0	0	1
Density				1.2

Appendix A.2. Continued.

	Longleaf pine		Slash pine	
Species	1980	1981	1980	198
Total				
N (individuals)	118	125	27	53
Density (birds/km)	147.5	156.2	35.8	66.
N (species)	21	20	9	18
Species diversity (H')[a]	1.6	1.6	0.7	1.
Biomass (kg)[b]	8.88	6.72	1.71	8.

[a] Shannon-Weiner index of species diversity (Shannon and Weaver 1949); mean values are reported.

[b] Biomass was estimated using mean-standard weights of individual species as reported in the literature (Appendix A.1).

Appendix A.3. Number (N) and density (birds/km) of birds observed during wintering seaso (December) censuses, Apalachicola National Forest, Florida, 1980 and 1981. Data were derived from a strip transect (40 m x 500 m; 131 ft x 1,640 ft) located in both natural longleaf and planted slas pine habitats in each of the 8 compartments; eac transect was censused 5 times.

	Longleaf pine		Slash pine	
Species	1980	1981	1980	1981
American robin				
N	22	0	37	0
Density	27.5		46.2	
Barred owl				
N	0	0	0	1
Density				1.2
Blue-gray gnatcatcher				
N	0	1	0	0
Density		1.2		
Brown-headed nuthatch				
N	11	3	0	0
Density	13.8	3.8		
Common yellowthroat				
N	1	0	1	0
Density	1.2		1.2	
Crow, American				
N	0	0	1	0
Density			1.2	
Eastern bluebird				
N	4	2	0	0
Density	5.0	2.5		
Eastern phoebe				
N	5	0	1	0
Density	6.2		1.2	
Hermit thrush				
N	1	0	1	0
Density	1.2		1.2	

ppendix A.3. Continued.

	Longleaf pine		Slash pine	
pecies	1980	1981	1980	1981
ourning dove				
N	0	0	0	1
Density				1.2
orthern mockingbird				
N	0	0	2	0
Density			2.5	
ed-shouldered hawk				
N	0	0	1	0
Density			1.2	
uby-crowned kinglet				
N	9	0	10	0
Density	11.2		12.5	
ufous-sided towhee				
N	0	1	4	0
Density		1.2	5.0	
olitary vireo				
N	0	0	2	2
Density			2.5	2.5
parrow, Bachman's				
N	5	1	0	1
Density	6.2	1.2		1.2
parrow, chipping				
N	17	0	0	2
Density	21.2			2.5
parrow, field				
N	0	0	1	0
Density			1.2	
Sparrow, song				
N	2	0	0	0
Density	2.5			
Sparrow, swamp				
N	6	0	0	0
Density	7.5			
Sparrow, white-throated				
N	18	0	0	0
Density	22.5			
Warbler, palm				
N	0	0	0	4
Density				5.0
Warbler, pine				
N	34	25	10	0
Density	42.5	31.2	12.5	
Warbler, yellow-rumped				
N	22	20	20	19
Density	27.5	25.0	25.0	23.8
Woodpecker, downy				
N	1	2	0	0
Density	1.2	2.5		
Woodpecker, hairy				
N	1	0	0	0
Density	1.2			
Woodpecker, red-bellied				
N	0	2	0	0
Density		2.5		
Woodpecker, red-cockaded				
N	4	9	2	0
Density	5.0	11.2	2.5	

Appendix A.3. Continued.

	Longleaf pine		Slash pine	
Species	1980	1981	1980	1981
Wren, Carolina				
N	2	0	1	0
Density	2.5		1.2	
Wren, house				
N	18	1	11	0
Density	22.5	1.2	13.8	
Wren, sedge				
N	21	11	8	1
Density	26.2	13.8	10.0	1.2
Yellow-bellied sapsucker				
N	4	5	0	1
Density	5.0	6.2		1.2
Total				
N (individuals)	208	83	113	32
Density (birds/km^2)	160.0	103.8	141.2	40.0
N (species)	21	13	17	9
Species diversity (H')[a]	1.5	0.7	1.0	0.3
Biomass (kg)[c]	4.67	1.70	5.22	1.13

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a/ Shannon-Weiner index of species diversity (Shannon and Weaver 1949); mean values are reported.

b/ Biomass was estimated using mean-standard weights of individual species as reported in the literature (Appendix A.1).

Appendix B.1. Common name, scientific name, and dominant mode of life for herpetofaunal species captured in trapping arrays, Apalachicola National Forest, Florida, 1980 and 1981.

Common name[a/]	Scientific name	Dominant mode of life[b/]
Coachwhip	*Masticophis flagellum*	T
Frog, little grass	*Limnaaedus ocularis*	SA
Frog, ornate chorus	*Pseudacris ornata*	SA
Frog, southern chorus	*Pseudacris nigrita*	SA
Frog, southern cricket	*Acris gryllus*	SA
Frog, southern leopard	*Rana sphenocephala*	SA
Green anole	*Anolis carolinensis*	AR

Appendix B.1. Continued.

Common name[a]	Scientific name	Dominant mode of life[b]
Lizard, eastern fence	Sceloporus undulatus	AR
Lizard, eastern glass	Ophisaurus ventralis	T
Lizard, slender glass	Ophisaurus attenuatus	T
Pigmy rattlesnake	Sistrurus miliarus	T
Racer	Coluber constrictor	T
Salamander, dwarf	Eurycea quadridigitata	SA
Salamander, flatwoods	Ambystoma cingulatum	T
Salamander, mole	Ambystoma talpoideum	F
Salamander, slimy	Plethodon glutinosus	T
Scarlet kingsnake	Lampropeltis triangulum	T
Six-lined racerunner	Cnemidophorus sexlineatus	T
Skink, broadhead	Eumeces laticeps	AR
Skink, five-lined	Eumeces fasciatus	T
Skink, ground	Scincella lateralis	T
Skink, southeastern five-lined	Eumeces inexpectatus	T
Snake, brown	Storeria dekayi	SA
Snake, common garter	Thamnophis sirtalis	SA
Snake, corn	Elaphe punctatus	T
Snake, eastern coral	Micrurus fulvius	T
Snake, eastern hognose	Heterodon platyrhinos	T
Snake, eastern ribbon	Thamnophis sauritus	SA

Appendix B.1. Continued.

Common name[a]	Scientific name	Dominant mod of life[b]
Snake, glossy crayfish	Regina rigida	A
Snake, pine	Pituophis melanoleucus	T
Snake, ringneck	Diadophis punctatus	T
Snake, scarlet	Cemophora coccinea	T
Snake, smooth earth	Virginia valeriae	T
Snake, southern hognose	Heterodon simus	T
Toad, eastern narrowmouth	Gastrophryne carolinensis	T
Toad, oak	Buto quercicus	T
Toad, southern	Bufo terrestris	T
Turtle, eastern box	Terrapene carolina	T
Turtle, eastern mud	Kinosternon subrubrum	A

[a] After Collins et al. (1982).

[b] Dominant mode of life designations: A = aquatic; AR = arboreal; F = fossorial; SA = semi-aquatic; T = terrestrial.

Appendix B.2. Census statistics for herpetofauna captured per array during spring (March-May) censuses, Apalachicola National Forest, Florida, 1980 and 1981. Data were derived from a 16-trap array operated in both natural longleaf and planted slash pine habitats in each of the 8 compartments for 8 consecutive weeks.

	Longleaf pine		Slash pine	
Species	1980	1981	1980	1981
Coachwhip				
N	1	2	0	0
Mean	0.1	0.2		
SD	0.4	0.7		
Frog, ornate chorus				
N	1	0	1	0
Mean	0.1		0.1	
SD	0.4		0.4	

pendix B.2. Continued.

pecies	Longleaf pine		Slash pine	
	1980	1981	1980	1981
nake, glossy crayfish				
N	1	0	1	0
Mean	0.1		0.1	
SD	0.4		0.4	
nake, ringneck				
N	0	1	0	0
Mean		0.1		
SD		0.4		
nake, scarlet				
N	13	18	3	2
Mean	1.6	2.2	0.4	0.2
SD	1.4	1.4	0.5	0.5
nake, smooth earth				
N	0	5	2	6
Mean		0.6	0.2	0.8
SD		0.5	0.5	1.8
nake, southern hognose				
N	0	1	0	0
Mean		0.1		
SD		0.4		
oad, eastern narrowmouth				
N	7	1	3	2
Mean	0.9	0.1	0.4	0.2
SD	1.1	0.4	1.1	0.5
oad, oak				
N	4	0	0	0
Mean	0.5			
SD	0.8			
oad, southern				
N	4	1	9	2
Mean	0.5	0.1	1.1	0.2
SD	1.1	0.4	2.2	0.7
urtle, eastern box				
N	1	0	2	0
Mean	0.1		0.2	
SD	0.4		0.5	
urtle, eastern mud				
N	4	0	0	0
Mean	0.5			
SD	0.9			

Appendix B.3. Census statistics for herpetofauna captured per array during fall (September-November) censuses, Apalachicola National Forest, Florida, 1980 and 1981. Data were derived from a 16-trap array operated in both natural longleaf and planted slash pine habitats in each of the 8 compartments for 8 consecutive weeks.

Species	Longleaf pine		Slash pine	
	1980	1981	1980	1981
Coachwhip				
N	0	0	0	1
Mean				0.1
SD				0.4
Eastern box turtle				
N	2	0	0	0
Mean	0.2			
SD	0.5			
Frog, little grass				
N	0	0	2	0
Mean			0.2	
SD			0.5	
Frog, ornate chorus				
N	1	0	2	0
Mean	0.1		0.2	
SD	0.4		0.5	
Frog, southern cricket				
N	1	0	1	0
Mean	0.1		0.1	
SD	0.4		0.4	
Frog, southern leopard				
N	7	0	1	1
Mean	0.9		0.1	0.1
SD	1.1		0.4	
Green anole				
N	2	0	3	11
Mean	0.2		0.4	1.4
SD	0.5		1.1	3.1
Lizard, eastern fence				
N	2	2	0	1
Mean	0.2	0.2		0.1
SD	0.5	0.7		0.4
Lizard, eastern glass				
N	0	2	2	2
Mean		0.2	0.2	0.2
SD		0.5	0.5	0.5
Lizard, slender glass				
N	1	1	0	0
Mean	0.1	0.1		
SD	0.4	0.4		
Pigmy rattlesnake				
N	4	0	3	2
Mean	0.5		0.4	0.2
SD	0.8		0.7	0.5

Appendix B.2. Continued.

	Longleaf pine		Slash pine	
Species	1980	1981	1980	1981
Frog, southern chorus				
N	0	0	1	0
Mean			0.1	
SD			0.4	
Frog, southern cricket				
N	1	0	1	0
Mean	0.1		0.1	
SD	0.4		0.4	
Frog, southern leopard				
N	7	1	1	0
Mean	0.9	0.1	0.1	
SD	1.2	0.4	0.4	
Green anole				
N	6	1	3	7
Mean	0.8	0.1	0.4	0.9
SD	2.1	0.4	0.7	1.1
Lizard, eastern fence				
N	1	1	1	2
Mean	0.1	0.1	0.1	0.2
SD	0.4	0.4	0.4	0.5
Lizard, eastern glass				
N	0	2	1	3
Mean		0.2	0.1	0.4
SD		0.7	0.4	0.7
Lizard, slender glass				
N	3	0	0	0
Mean	0.4			
SD	0.7			
Pigmy rattlesnake				
N	1	2	0	1
Mean	0.1	0.2		0.1
SD	0.4	0.5		0.4
Racer				
N	10	7	8	7
Mean	1.2	0.9	1.0	0.9
SD	1.0	0.6	1.8	0.8
Salamander, dwarf				
N	3	1	5	0
Mean	0.4	0.1	0.6	
SD	1.1	0.4	0.7	
Salamander, flatwoods				
N	2	0	3	0
Mean	0.2		0.4	
SD	0.7		0.7	
Salamander, mole				
N	0	0	2	0
Mean			0.2	
SD			0.7	

Appendix B.2. Continued.

	Longleaf pine		Slash pine	
Species	1980	1981	1980	198
Salamander, slimy				
N	3	5	0	2
Mean	0.4	0.6		0
SD	0.7	0.9		0
Scarlet kingsnake				
N	0	1	0	1
Mean		0.1		0
SD		0.4		0
Six-lined racerunner				
N	18	23	4	16
Mean	2.2	2.9	0.5	2
SD	3.9	3.7	1.4	5
Skink, broadhead				
N	3	12	0	8
Mean	0.4	1.5		1
SD	0.5	1.9		2
Skink, ground				
N	27	47	16	84
Mean	3.4	5.9	2.0	10
SD	2.7	6.0	1.6	8
Skink, southeastern five-lined				
N	2	2	2	0
Mean	0.2	0.2	0.2	
SD	0.7	0.5	0.5	
Snake, brown				
N	0	0	1	0
Mean			0.1	
SD			0.4	
Snake, common garter				
N	2	4	1	2
Mean	0.2	0.5	0.1	0.
SD	0.5	0.8	0.4	0.
Snake, corn				
N	1	3	0	1
Mean	0.1	0.4		0.
SD	0.4	0.5		0.
Snake, eastern coral				
N	1	2	0	2
Mean	0.1	0.2		0.
SD	0.4	0.5		0.
Snake, eastern hognose				
N	1	0	0	0
Mean	0.1			
SD	0.4			
Snake, eastern ribbon				
N	3	1	4	5
Mean	0.4	0.1	0.5	0.
SD	0.7	0.4	0.8	1.

pendix B.3. Continued.

	Longleaf pine		Slash pine	
ecies	1980	1981	1980	1981
ter				
N	0	3	7	7
Mean		0.4	0.9	0.9
SD		0.7	1.0	1.0
lamander, dwarf				
N	5	0	6	0
Mean	0.6		0.8	
SD	0.9		0.9	
lamander, flatwoods				
N	1	0	0	2
Mean	1			0.2
SD	0.4			0.7
arlet kingsnake				
N	0	0	0	1
Mean				0.1
SD				0.4
x-lined racerunner				
N	2	4	2	1
Mean	0.2	0.5	0.2	0.1
SD	0.5	0.8	0.7	0.4
ink, broadhead				
N	1	0	0	0
Mean	0.1			
SD	0.4			
ink, five-lined				
N	1	0	0	0
Mean	0.1			
SD	0.4			
ink, ground				
N	15	14	33	6
Mean	1.9	1.8	4.1	0.8
SD	2.1	2.3	6.3	1.8
ink, southeastern five-lined				
N	2	1	0	1
Mean	0.2	0.1		0.1
SD	0.5	0.4		0.4
ake, common garter				
N	0	0	1	0
Mean			0.1	
SD			0.4	
ake, corn				
N	1	0	0	0
Mean	0.1			
SD	0.4			
ake, eastern coral				
N	1	3	1	2
Mean	0.1	0.4	0.1	0.2
SD	0.4	0.7	0.4	0.5

Appendix B.3. Continued.

	Longleaf pine		Slash pine	
Species	1980	1981	1980	1981
Snake, eastern ribbon				
N	0	0	1	1
Mean			0.1	0.1
SD			0.4	0.4
Snake, glossy crayfish				
N	0	1	0	0
Mean		0.1		
SD		0.4		
Snake, pine				
N	0	1	0	0
Mean		0.1		
SD		0.4		
Snake, ringneck				
N	1	0	0	1
Mean	0.1			0.1
SD	0.4			0.4
Snake, scarlet				
N	1	0	0	0
Mean	0.1			
SD	0.4			
Snake, smooth earth				
N	1	9	5	7
Mean	0.1	1.1	0.6	0.9
SD	0.4	2.0	1.2	1.4
Toad, eastern narrowmouth				
N	0	7	0	3
Mean		0.9		0.4
SD		1.4		0.7
Toad, oak				
N	1	1	0	0
Mean	0.1	0.1		
SD	0.4	0.4		
Toad, southern				
N	0	0	0	1
Mean				0.1
SD				0.4

Appendix C.1. Census statistics for small mammals captured per transect during spring (May) censuses, Apalachicola National Forest, Florida, 1980 and 1981. Data were derived from a 375-m (1,230-ft), 25-station transect, with 1 live trap and 1 snap trap per station, operated in both natural longleaf and planted slash pine habitats in each of the 8 compartments for 4 consecutive nights.

	Longleaf pine		Slash pine	
Species	1980	1981	1980	1981
Cotton mouse (*Peromyscus gossypinus*)				
N	20	9	29	2
Mean	2.5	1.1	3.6	0.2
SD	2.4	1.1	3.1	0.5
Cotton rat (*Sigmodon hispidus*)				
N	33	9	15	6
Mean	4.1	1.1	1.9	0.8
SD	4.5	1.7	1.9	0.9
House mouse (*Mus musculus*)				
N	0	1	0	0
Mean		0.2		
SD		0.5		
Least shrew (*Cryptosis parva*)				
N	2	2	3	0
Mean	0.2	0.2	0.4	
SD	0.5	0.5	0.5	

Appendix C.2. Census statistics for small mammals captured per transect during fall (October) censuses, Apalachicola National Forest, Florida 1980 and 1981. Data were derived from a 375-m (1,230-ft), 25-station transect, with 1 live trap and 1 snap trap per station, operated in both natural longleaf and planted slash pine habitats in each of the 8 compartments for 4 consecutive nights.

	Longleaf pine		Slash pine	
Species	1980	1981	1980	1981
Cotton mouse (*Peromyscus gossypinus*)				
N	15	2	12	4
Mean	1.9	0.2	1.5	0.5
SD	2.2	0.7	1.8	1.1

Appendix C.2. Continued.

	Longleaf pine		Slash p
Species	1980	1981	1980
Cotton rat (*Sigmodon hispidus*)			
N	6	2	14
Mean	0.8	0.2	1.8
SD	0.7	0.5	3.2
Least shrew (*Cryptosis parva*)			
N	1	4	0
Mean	0.1	0.5	
SD	0.4	0.8	
Southern short-tailed shrew (*Blarina carolinensis*)			
N	0	0	1
Mean			0.1
SD			0.4

Longleaf-Slash Pine Type Discussion

estion

Were understory vegetation data collected by pine type similar to Florida collections? Also, are tural savannas in Florida being converted to pine plantations with bedding and chopping?

sponse

About 60% of the Louisiana area had longleaf pine and 20% slash pine; only one area in Mississippi had y slash pine plantations. The workshop reports do not distinguish between the pines since understory getation characteristics did not appear different. However, the basic data records the understory for ch specific overstory type.

The savanna sites in Florida are currently protected and are not being planted to slash pine.

The Florida data indicate greater wildlife diversity in natural longleaf pine stands compared with ash pine plantations. This does not suggest that longleaf pine plantations will be more diverse than ash pine plantations.

In Mississippi, some bedding is being done; however, prior to bedding, sites are reviewed by the rest Service botanist to determine if sensitive plants (threatened, endangered, etc.) exist on the sites. gs are essentially protected from all site preparation activities.

estion

Can comments regarding discrepancies in areas grazed in Louisiana be resolved?

sponse

Originally (1979-80) when vegetation measurements were made, all 4 study areas were grazed by cattle; azing was discontinued on area 4 by the time of the wildlife measurements (1981-82). Areas 1, 2, and 3 re grazed during all measurements.

estion

Did sawtimber in the Louisiana study have a mosaic pattern with a lot of edge that may have influenced e wildlife numbers?

sponse

The sawtimber had a more diverse habitat with abundant understory growth, down logs, and litter for phibians and reptiles.

In Florida, there are distinct islands of longleaf pine in wet areas and Bladden soils but only the rger tracts of contiguous stands were sampled for wildlife to avoid the edge effect.

In Mississippi there were several herpetafauna that were considered as transients that normally would t have been expected in a particular stand class. During dry periods, some species were found apparently ving toward water.

estion

Have the Southeast National Forests ever been considered from the standpoint of biological islands oviding refuge for biological diversity--especially as related to disease outbreaks, droughts, or other saster?

sponse

The National Forest planning effort recognizes this diversity and will continue to support habitat versity on those biological islands. As we learn more about the biological interrelationship, planning d action will continue to improve maintenance of biological diversity.

estion

Why did herbage production average 1100 lb/ac at zero basal area (BA), then decrease in the next gher BA class, but then increase in the next higher BA class?

Response

This was probably due to sampling error. Differences in herbage yield were not statistically different for the lower BA classes. Herbage yields above 100 ft^2/acre BA were significantly less than tho below 100 ft^2/acre BA.

Question

What is the normal occurrence of legumes in the botanical composition where an area has a history fire and grazing? Also, what recovery period or opportunity is there for legumes to return to these ar?

Response

Some work in Mississippi indicates that legumes may not increase with continued burning, even in t absence of cattle. Even with disking there was no increase in legumes--presumable because there was no seed source. Legumes could be seeded but they would disappear in a few years without control of other petition.

Further north, the legume seed source is not a problem. Just disk, plow, chop, or crush, and then burn and legumes respond fantastically.

Question

How critical are legumes in the longleaf type for quail populations?

Response

Pine seed is excellent for quail but you cannot depend on it as the main winter quail food. Where food plots are well distributed and legumes abundant, you can expect 1 to 4 birds/acre. You will not ge quail/acre in the longleaf pine-wiregrass type without habitat improvements.

Question

Are there differences in quail populations due to size or period of burn and length of rotation between burns? Large areas on the National Forest are usually burned because of economics and practicality

Response

A 200-300 acre burn interspersed with nonburned areas would be great. A mosaic of burned areas, so cool, some hot, with cover scattered around for escape would be ideal. Annual burns in Alabama were compared to burns where cover was left; quail survival rates have been better where cover was left. The mo critical time for quail is from just after an early March burn until the vegetation cover grows back in June. The burning pattern (mosaic) is important to provide cover.

WATERSHEDS, SOCIOECONOMICS, AND FOREST PESTS

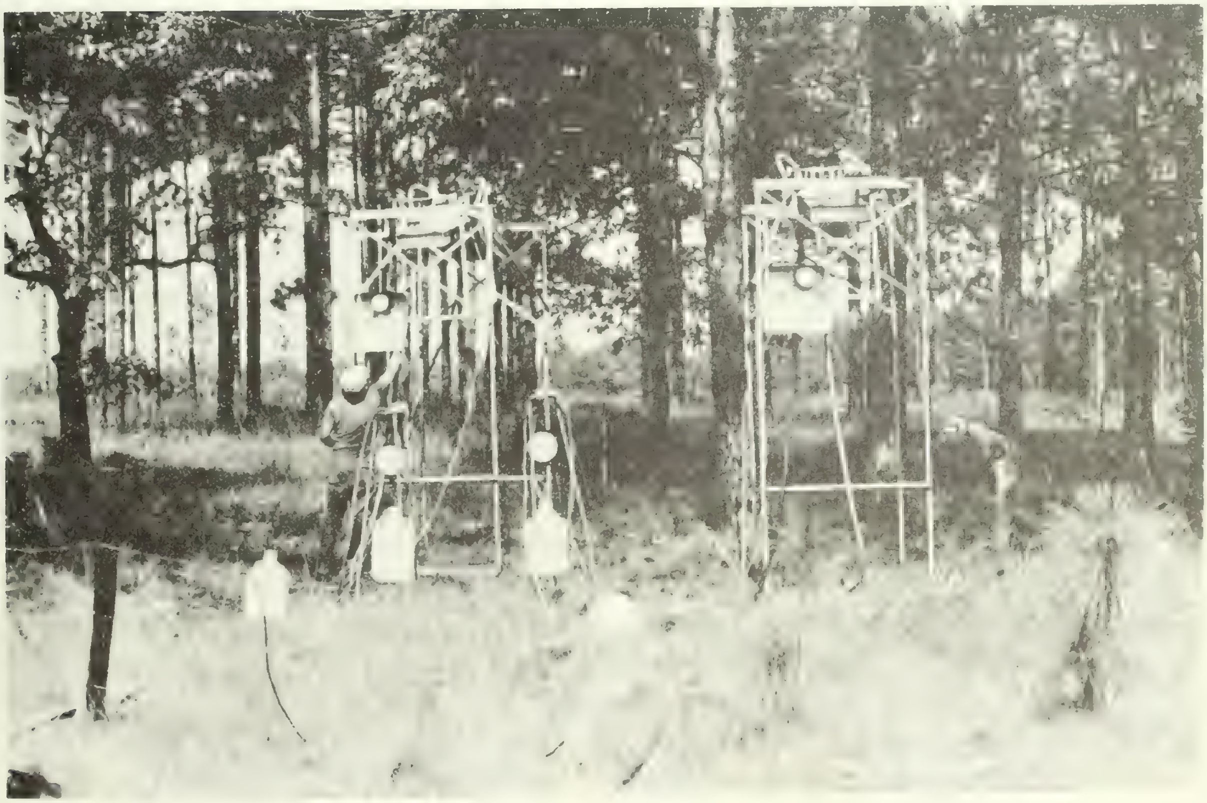
Moderators:

Robert C. Joslin
Kisatchie National Forest
Pineville, Louisiana

and

Dan W. Speake
USDI Fish and Wildlife Service
Auburn, Alabama

The big challenge facing forestry in the South is to maintain an acceptable forest environment while managing for timber, livestock, wildlife, and recreation. The Clean Water Act requires identification and control of activities that contribute to nonpoint source pollution. Socioeconomic factors are little understood components of traditional southern agriculture especially as they relate to forestry and livestock grazing. Interrelationships among range, wildlife, and tree pests are not fully understood. The implications of insects and diseases that attack trees are important considerations for forest range management.



Storm Flow and Sediment Loss from Intensively Managed Forest Watersheds in East Texas

W. H. Blackburn, J. C. Wood, H. A. Pearson, and R. W. Knight[1]

Abstract.--Five small (12-acre) forested watersheds in East Texas were instrumented in December 1980 to determine the effect of forest harvesting, mechanical site preparation, and livestock grazing on storm flow, peak discharge rate, and sediment loss. After three years of pre-treatment calibration, four of the watersheds were treated as follows: (1) clearcutting followed by roller chopping; (2) clearcutting followed by shearing, and windrowing; (3) clearcutting followed by shearing, windrowing, and rotational grazing; and (4) clearcutting followed by shearing, windrowing, and continuous grazing. Clearcut harvesting and all site preparation treatments significantly increased storm flow, peak discharge rates, and sediment losses over the undisturbed watershed. Properly stocked livestock grazing appeared to have little impact on sediment loss or storm flow. Sediment losses from these intensively managed watersheds, even though significantly greater, were within the range of sediment losses from undisturbed watersheds in the Southeast, below the range of losses from mechanically prepared watersheds elsewhere, and well below potential losses from pasture and cropland. Roller chopping, and shearing and windrowing are recommended as environmentally sound forest practices on watersheds with slopes up to 8 percent.

INTRODUCTION

Current and projected water shortages for exas make the water-rich, commercial forestlands f East Texas extremely important to the State's uture growth and development. However, little is nown in Texas about the influence of intensive orest practices or livestock grazing on sediment oss or storm flow.

The Southern States are currently producing ore than half of the nation's wood supply with emands expected to increase timber production in he next 20 years. The challenge facing forestry n the South is to develop technology and anagement to meet this increased demand while aintaining an acceptable forest environment in he face of increased taxes and rising costs of abor, equipment, and energy. The intensive orest management practices of harvesting, site preparation, and livestock grazing have been identified as potential sources of declining site productivity and nonpoint pollution. The Clean Water Act (PL 92-500 and PL 95-217) requires identification and control of silvicultural and livestock grazing activities that contribute to nonpoint source pollution.

Because of: (1) the long history of woodland overgrazing; (2) poorly designed studies to evaluate proper livestock grazing; and (3) lack of forest hydrology research that applies to grazing, the conservation-minded public continues to perceive forest grazing as an urgent environmental problem (Adams 1975, Johnson 1952, Lee 1980, Patric and Helvey 1986). Most studies in the eastern United States have evaluated only the impacts of heavy continuous grazing or have misused soil loss prediction equations such as the Universal Soil Loss Equation to evaluate forest

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grazing (Blackburn 1984, Patric and Helvey 1986). Dissmeyer (1976) using his First Approximation of Suspended Sediment (FASS) method to evaluate soil loss in the Southeast stated that overgrazing of woodlands is clearly a major source of soil erosion.

Forest management activities have the potential to influence storm-flow amount and timing. The first year following site preparation near Alto, Texas, storm flow was significantly greater from watersheds that had been clearcut, followed by shearing, windrowing, and burning (5.7 inch) than from watersheds that were clearcut, followed by roller chopping and burning (3.3 inch). Storm flow from the latter treatment was greater than from the undisturbed watersheds (1.1 inch) (Blackburn and others 1986). Storm flow decreased from the site-prepared watersheds after the first post-treatment year, but was still greater during the fourth post-treatment year from the sheared (2.4 inch) and chopped (1.4 inch) watersheds than from the undisturbed (0.6 inch) watersheds.

The natural sediment loss from undisturbed forest varies with location, soil, geology, vegetation, watershed size, and season. Research in the Southeast has demonstrated that natural erosion rates from undisturbed forestland are low, ranging from a trace to 640 lb/acre/year (Beasley 1982, Schrieber and others 1980, Yoho 1980). First year sediment losses were greater from the sheared watersheds (2,620 lb/acre) at Alto, Texas than from the chopped (22 lb/acre) or undisturbed (29 lb/acre) watersheds (Blackburn and others 1986). Although second-year sediment losses were greatly reduced from the sheared watersheds, they remained greater than the chopped or undisturbed watersheds for at least four years.

The objective of this study was to assess the impact of clearcut harvesting, mechanical site preparation, and livestock grazing on soil erosion, storm flow, and sediment loss.

STUDY AREA

The study site consisted of five 12-acre instrumented watersheds located about 35 miles east of Lufkin, Texas on the Angelina National Forest in western San Augustine County. The study area is characterized by gentle rolling topography intersected with numerous drainages. Slopes range from 1 to 8 percent. Overstory vegetation prior to harvesting was predominantly loblolly pine (Pinus taeda L.), longleaf pine (Pinus palustris P. Mill.), shortleaf pine (Pinus echinata P. Mill), red oak (Quercus falcata var. falcata Michx.), and sweetgum (Liquidambar styraciflua L.). The watersheds are located in the northern part of the Yegua geologic formation which is mainly acid stratified sandstone and shale with some areas underlain by variable amounts of siltstone. The soils are of the Cuthbert or Kirvin series, which are classified as clayey, mixed, thermic typic Hapludults. They have a fine-textured, sandy loam A horizon up to 10 inches thick, and a clay-textured B horizon. th soil series are found extensively throughout t Texas and much of the southern Coastal Plain. Mean annual temperature is 66 °F with an aver frost-free season of 246 days. Normal annual precipitation of 48 inches is fairly well-distributed throughout the year (NOAA 1981) wi slightly more precipitation occurring during April, May, November, December, and January.

METHODS AND PROCEDURES

Treatments

The five watersheds were instrumented in 30 and stream flow monitoring began in January 19. Calibration relationships were developed from January 1981 through October 1983 between four treatment watersheds and one control watershed (Table 1).

Harvesting of an 80-acre clearcut in conjunction with watershed 1 began October 26, 1983 and ended December 28, 1983. Approximate 15 percent of the upper portions of watersheds 3, and 4 was harvested in conjunction with ano 76-acre clearcut beginning October 19, 1983 an ending November 10, 1983. The remaining porti of watersheds 2, 3, and 4 were clearcut betwee May 22, 1984 and June 25, 1984. Watershed 2 w roller chopped on October 9, 1984. Approximat 50 percent of watershed 1 was sheared between November 11, 1984 and December 10, 1984. The remaining half was sheared and windrowed betwe May 20, 1985 and May 31, 1985. Shearing and windrowing of watershed 3 and 4 took place, fo the most part, between May 31, 1985 and June 1 1985. All silvicultural practices were perfor under the direction of the Angelina Ranger District and followed "state-of-the-art method in compliance with Forest Service policy.

Forty longhorn cattle with some calves unc 6 months of age grazed the study area's approximately 1,400 acres for six weeks beginning Aug 1, 1984. The overall stocking rate was about acres/Animal Unit Month (AUM). Livestock were excluded from watersheds 2, 3, and 5 by electri fences. Although approximately 1,400 acres we available for livestock grazing during this six-week period, animals concentrated on the tw clearcut areas.

Watershed 1 and the adjacent clearcut area was grazed continuously for four months under a moderate stocking rate (2.5 acres/AUM) beginnin July 1, 1986 and ending October 31, 1986. Watershed 4 and the adjacent clearcut area was grazed in a manner which simulated one-pasture an eight-pasture intensive rotation grazing system. Periods of grazing were dependent on forage availability, quality, and plant physiological stage. After each grazing period cattle were removed and the pasture was allowed rest. Rest periods were determined as the equivalent time that would be required to rotationally graze seven additional pastures of equal size and carrying capacity. During 1986

Table 1.--Schedule of silvicultural and livestock grazing treatments as applied to the five experimental watersheds, Angelina National Forest, Texas

Watershed	Undisturbed	Clearcut	Site Preparation	Grazed
1	Jan. 1, 1981 to Oct. 26, 1983	Oct. 26, 1983 to Dec. 28, 1983	Sheared/windrowed 50%, Nov. 11, 1984 to Dec. 10, 1984 50%, May 20, 1985 to May 31, 1985	Continuous July 1, 1986 to Oct. 31, 1986 (2.5 acre/AUM)
2	Jan. 1, 1981 to Oct. 19, 1983	15%, Oct. 19, 1983 to Nov. 10, 1983 85%, May 22, 1984 to June 25, 1984	Roller chopped Oct. 9, 1984	None
3	Jan. 1, 1981 to Oct. 19, 1983	15%, Oct. 19, 1983 to Nov. 10, 1983 85%, May 22, 1984 to June 25, 1984	Sheared/windrowed May 31, 1985 to June 12, 1985	None
4	Jan. 1, 1981 to Oct. 19, 1983	15%, Oct. 19, 1983 to Nov. 10, 1983 85%, May 22, 1984 to June 25, 1984	Sheared/windrowed May 31, 1985 to June 12, 1985	Rotation July 1-6, 1986 Aug. 18-25, 1986 Oct. 22-31, 1986 (2 acres/AUM)
5	Jan. 1, 1981 to Dec. 30, 1986	None	None	None

watershed 4 underwent three grazing periods with a comparative stocking rate of about 2 acres/AUM: (1) a six-day grazing period from July 1 to July 6 with a 42 day rest; (2) an eight-day grazing period from August 18 to August 26 with a 56 day rest; and (3) a 10-day grazing period from October 22 to October 31 followed by winter deferment of approximately five months.

Precipitation was measured in Forester type rain gauges located in a network that has one gauge for each five acres. Rainfall intensity and duration were obtained from recording rain gauges (Belfort Weighing). The erosion index (EI) of individual storms was calculated using the procedure outlined by Wischmeier and Smith (1978). Storm flow volume and rate were measured with three-foot H-flumes equipped with FW-1 Type water level recorders. Flume approach sections were 12 feet long. Suspended sediment samples were collected at each flume with a Coshocton wheel sampler coupled to a splitter constructed from four-inch PVC water pipe. The water samples collected by the Coshocton wheel (about 0.5 percent of total flow) were further divided by a factor of 10 as they flowed through the splitter. The water samples were collected in 50-gallon chemically inert containers. Homogeneous subsamples were collected for laboratory analysis usually within one day following each runoff event.

Coarse sediments were collected in a 20 x 68 x 9 inch drop box located at the front of the approach section to each flume. A subsample was collected, oven-dried at 221 °F, weighed, and multiplied by the volume of sediment deposited. Suspended sediment was determined by vacuum-filtering one quart subsamples of the Coshocton wheel water sample through 1.78×10^{-5} inch filters, oven drying at 221 °F, and weighing. Total sediment loss was the product of the discharge weighted-Coshocton wheel samples and drop box samples, expressed in lb/acre.

Ground cover was measured by point-sampling (Levy and Madden 1933) at 8-inch intervals along twenty-five, 65-foot transects distributed in a stratified random pattern. Surface cover was classified as litter, slash, live vegetation, rock, or mineral soil. If mineral soil was exposed, it was recorded as non-eroded, interrill or rill erosion, or deposition.

Due to the extreme variability in rain storm frequency, size, intensity, and duration, and, more importantly, the response of each experimental watershed to these variations, statistical analysis of rainfall data was separated into two parts: (1) events without storm flow from the undisturbed watershed; and (2) events with storm flow from the undisturbed watershed. In both cases, regression models were used to test for treatment differences in storm flow and sediment loss. In the first case, where storm flow did not occur from the undisturbed watershed, regression models for watershed responses of storm flow, and sediment loss were fit with watershed and treatment effects. In the second case, where storm flow did occur from the undisturbed watershed, the same regression models were used and the undisturbed watershed was included as a covariate in the model. All storm flow response variables were adjusted using a natural log transformation in order to fulfill the assumption of normality necessary for the statistical procedures used in this analysis.

RESULTS AND DISCUSSION

Ground Cover

Prior to treatment, mean ground cover for the five watersheds was 92 percent mulch, 3 percent slash, and 3 percent live vegetation (Table 2). Mineral soil was exposed on 2 percent of the watersheds with no evidence of rill or interrill erosion.

After site preparation, in August 1985, mineral soil was exposed on 8.1 percent of the chopped watershed, 37.5 percent of the sheared watershed, and 30.9 and 31.3 percent of the sheared/grazed watersheds. Herbaceous vegetation, slash and mulch covered most of the site prepared watersheds after two growing seasons. Exposed mineral soil was reduced to 10 percent or less by October 1986 on the sheared and sheared/grazed watersheds and to 8.1 percent by August 1985 on the chopped watershed.

Precipitation

Annual precipitation was above normal for all six years of the study (NOAA 1981) (Table 3). Although above normal precipitation occurred during 1981 and 1985, they were the drier of the six years and 1982 and 1986 were the wettest years.

Precipitation during 1986 was above normal for all months except January and March, but during 1985 precipitation was above normal for only five months (Fig. 1). Variation in rainfall amount, intensity, duration, and frequency of occurrence caused considerable variation in storm flow. Most precipitation events were too small or too infrequent to generate storm flow. Because of high evapotranspiration and low antecedent soil moisture, larger, more frequent rainfall events were necessary during late spring and summer than during late fall and winter to generate storm flow. As a result of these conditions, only one storm flow event occurred during 1981.

The largest rainfall event (8.8 inch) occurred on November 22, 1986. Rainfall even of 3.5 to 3.9 inches occurred on October 9, 1982 August 3, 1983, February 11, 1984, October 29 1985, and September 21, 1986.

Storm Flow

Storm flow from the watersheds was influe ed by: (1) antecedent soil moisture conditions;) rainfall amount, intensity, and duration; and watershed conditions such as size, shape, slop vegetation, ground cover, and soil.

One storm flow event occurred during 1981, with 20 and 21 events during 1982 and 1983, respectively. Pre-treatment annual storm flow expressed as a percentage of precipitation averaged less than 0.5 percent in 1981 compare o 9.4 percent in 1982 and 10.6 percent in 1983. Storm flow after various stages of harvesting, site preparation, and livestock grazing averag 21.4 percent of precipitation in 1985 and 26.7 percent of precipitation in 1986.

Rainfall events generated storm flow from least one watershed 43 times during 1984, 26 t s during 1985, and 39 times during 1986. From 1 through 1986 the sheared/windrowed watershed generally yielded the greatest storm flow and peak discharge rate (Table 3) followed by shea / rotationally grazed, chopped, sheared/continuo y grazed, and undisturbed watersheds.

Storm flow for each treated watershed was cumulated and plotted against the cumulated counterpart for the undisturbed watershed (Fig. 2). Clearcut harvesting resulted in significan increases ($p < .05$) in storm flow relationships relative to pre-harvesting. Clearcut harvestin reduced evapotranspiration and increased soil moisture available to stream flow. Forest floo disturbance associated with harvesting may have reduced soil infiltration rates, thus increasin overland flow.

The effects of site preparation, either shearing/windrowing, or roller chopping on stor flow, although dwarfed by the sharp increases already resulting from clearcut harvesting, wer significant. The additional increases in storm flow resulting from site preparation were proba due to the further reduction in standing vegetation and additional soil surface disturbance. The increase in storm flow follow forest harvesting and/or site preparation follo a generalized pattern that has been repeatedly documented (Blackburn and others 1986, Douglas 1983, Hewlett 1979, Hornbeck 1975). Storm flow and peak discharge rates tended to be greater f the sheared watersheds than from the chopped watershed. This was probably due to the greate soil disturbance (Table 1) associated with the shearing/windrowing treatment than with the chopping treatment.

Roller chopping tended to reduce storm flo by covering the ground with a protective layer o litter and slash, and by increasing microrelief the result of roller chopper blade depressions.

Table 2.--Pre- and post-treatment watershed groundcover (%) and erosion (%), Angelina National Forest, Texas

	Pre-treatment (1981-1983)	Post-treatment							
		August 1985				October 1986			
	All Watersheds	Chopped (WS 2)[1]	Sheared (WS 3)	Sheared/ Pregrazed (WS 4)	Sheared/ Pregrazed (WS 1)	Chopped (WS 2)	Sheared (WS 3)	Sheared/ Grazed (WS 4)	Sheared/ Grazed (WS 1)
Mulch	92	1.8	1.3	3.5	4.6	13.3	8.8	10.4	12.0
Slash	3	70.0	57.6	55.6	48.6	26.8	17.3	17.5	19.8
Seedlings, Woody	t[2]	1.6	0.6	1.2	1.9	4.0	2.1	0.9	3.6
Vine	t	0.6	t	0.3	1.4	2.8	0.1	0.3	0.9
Forb	t	1.9	0.6	1.4	2.6	2.8	3.8	2.3	2.8
Grass like	t	0.3	t	0.5	t	0.8	0.3	2.4	t
Grass	3	16.0	2.4	7.1	9.7	47.7	57.6	61.0	50.8
Mineral Soil	2	8.1	37.5	30.9	31.3	2.1	8.8	5.2	10.1
No Erosion	2	8.0	37.0	30.4	31.3	1.9	5.1	4.0	8.7
Deposition	0	0.1	0.2	0.5	0	0.2	0.7	0.4	1.1
Rill	0	0	0.3	0	0	0	0	0	0
Interrill	0	0	0	0	0	0	3.0	0.8	0.2

[1] WS = watershed.

[2] t = trace.

Table 3.--Annual pre- and post-treatment[1] precipitation, storm flow, mean peak discharge rate, and sediment loss by watershed (1981-1986), Angelina National Forest, Texas

Parameter	Treatment	Watershed	Pre-treatment 1981	Pre-treatment 1982	Pre-treatment 1983	Post-treatment 1984	Post-treatment 1985	Post-treatment 1986
Precipitation (inch)	Undisturbed	5	48.7	66.2	56.3	53.4	52.5	65.1
	Chopped	2	49.4	65.2	57.4	52.8	49.4	64.8
	Sheared	3	48.8	64.2	56.9	51.8	48.4	63.3
	Sheared/Grazed, Rotation	4	48.8	64.2	56.9	51.8	48.4	63.3
	Sheared/Grazed, Continuous	1	48.1	62.4	56.3	51.8	47.4	61.5
Storm flow (inch)	Undisturbed	5	<0.1	5.8	5.1	3.4	1.4	5.6
	Chopped	2	0.2	5.3	5.3	8.8	8.2	15.6
	Sheared	3	0.2	9.0	8.3	13.5	14.0	21.0
	Sheared/Grazed, Rotation	4	<0.1	4.8	5.7	9.5	10.6	15.7
	Sheared/Grazed, Continuous	1	<0.1	5.9	6.2	10.1	9.6	15.4
Peak Discharge Rate (cfs)	Undisturbed	5	0.4	0.9	0.6	0.6	0.2	1.2
	Chopped	2	0.6	0.9	0.8	1.0	1.4	1.3
	Sheared	3	0.6	0.9	0.7	1.3	1.8	1.6
	Sheared/Grazed, Rotation	4	0.3	0.8	0.7	1.2	1.5	1.4
	Sheared/Grazed, Continuous	1	0.2	0.8	0.9	1.2	1.3	1.2
Sediment Loss (lb/acre	Undisturbed	5	1.8	80.6	38.6	32.2	18.0	244.8
	Chopped	2	2.0	38.4	58.2	151.4	76.3	150.4
	Sheared	3	2.4	90.2	70.1	272.7	164.6	158.4
	Sheared/Grazed, Rotation	4	11.4	37.1	30.6	92.8	106.8	275.4
	Sheared/Grazed, Continuous	1	*	35.9	37.4	95.4	73.9	99.3

[1] The chopped watershed was harvested during November and December 1983 and site prepared on October 9, 1984. Harvesting was completed on the sheared watersheds during May and June 1984 and were site prepared during May and June 1985.

* No sample collected.

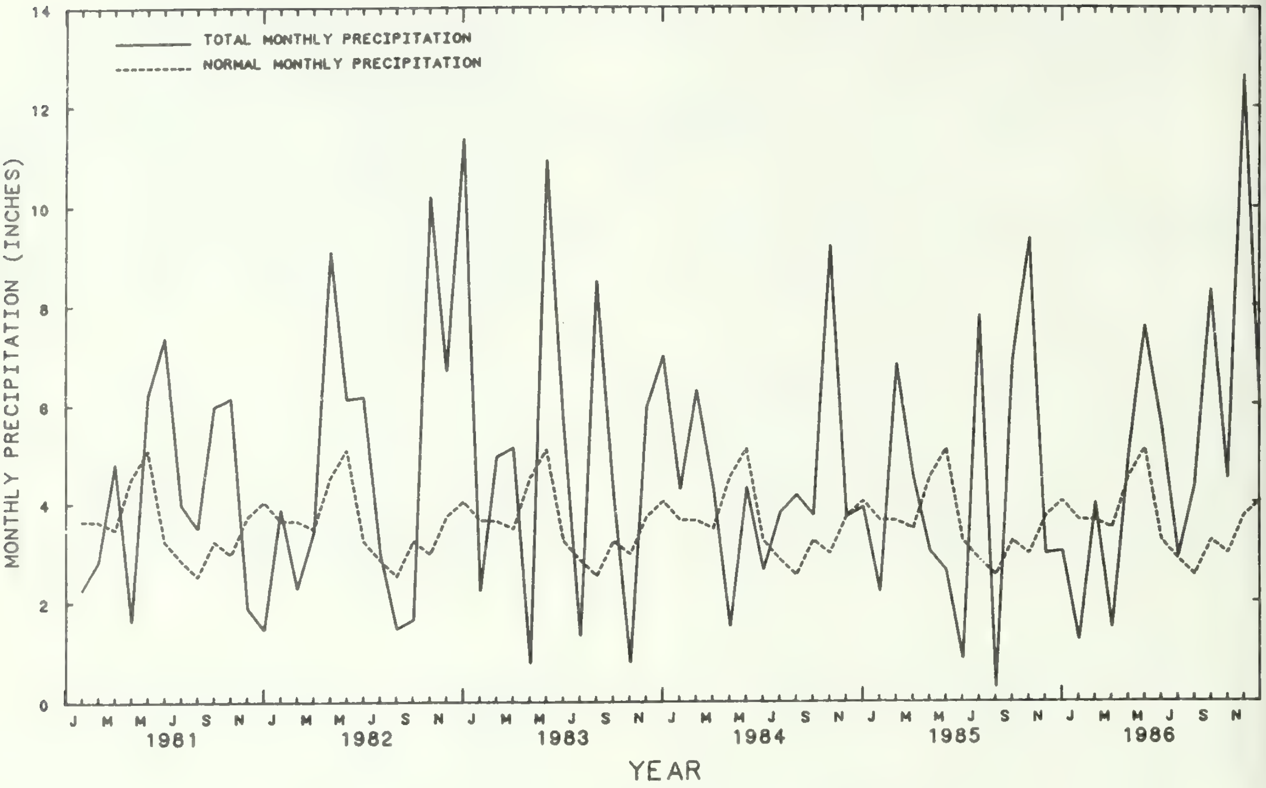


Figure 1.--Total monthly and normal monthly precipitation for the study period, Angelina National Forest Texas.

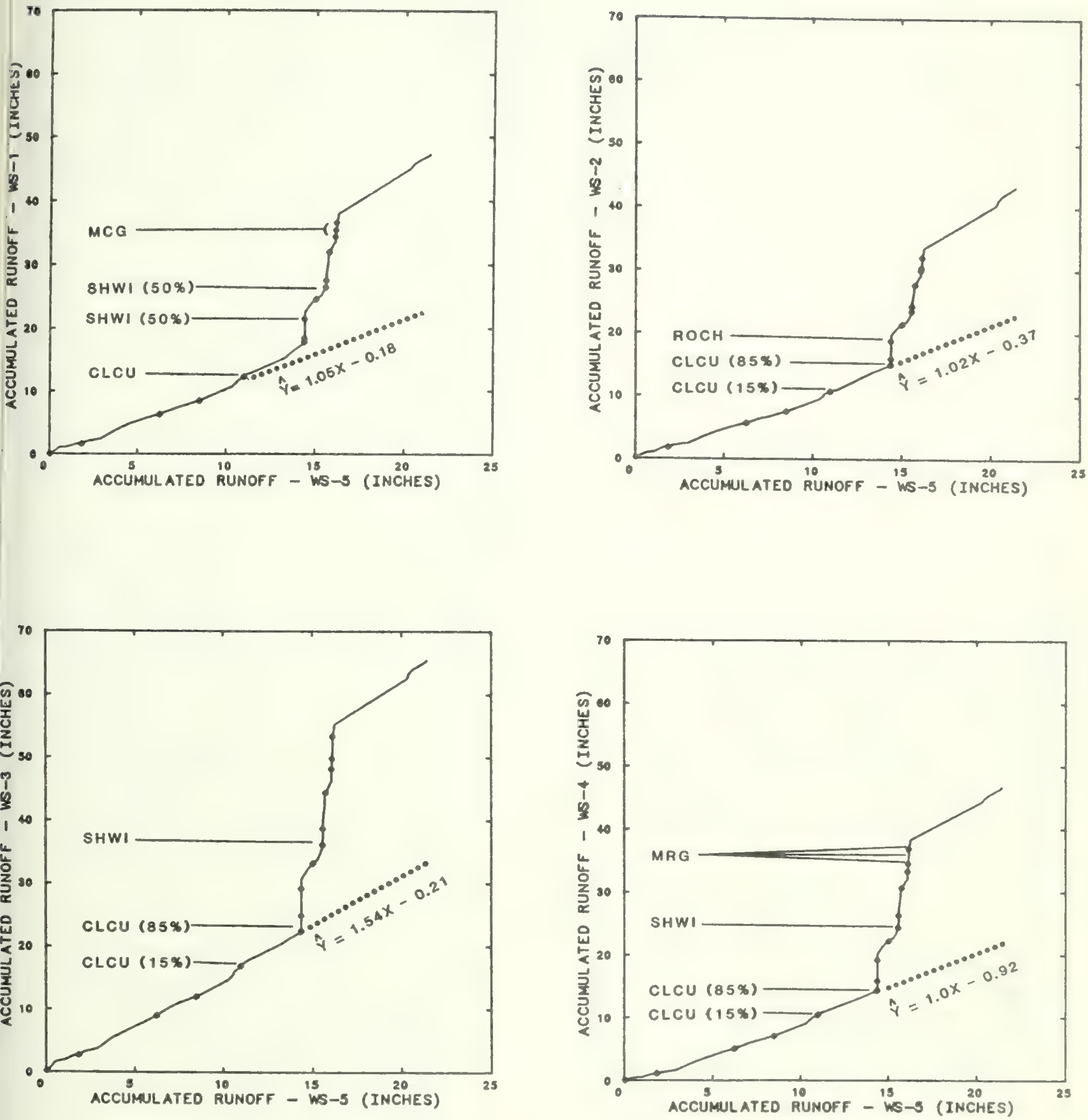
These factors were apparently quite effective in reducing storm flow and peak discharge rates of the smaller rainfall events but had little influence on the larger events. Livestock grazing had no significant impact on storm flow.

Sediment

Annual sediment loss during the three pre-treatment years was generally less than 89 lb/acre from each watershed (Table 3). Sediment loss from the undisturbed watershed ranged from 0.8 to 244 lb/acre; sediment loss from the treated watersheds ranged from 74 to 275 lb/acre. These values are well within the range of sediment loss (trace to 640 lb/acre) reported for southeastern undisturbed forested watersheds (Yoho 1980). Periodic flushing of sediment collected in the stream channel as a result of bank sloughing, rodents, small mammal or insect activity accounts for most of the occasional high sediment loss from undisturbed watersheds. These channel activities and the increased storm flow probably accounted for most of the sediment lost from the treated watersheds.

Sediment loss was significantly increased by clearcut harvesting and site preparation (Fig. 3). However, total cumulative sediment loss during the six years of this study ranged from less than 342 to 758 lb/acre, just over the range of annual sediment loss reported for undisturbed forested watersheds in the Southeast (Yoho 1980). The lowest cumulative sediment loss occurred from th clearcut, sheared, windrowed, and continuously grazed watershed, not from the undisturbed watershed.

The watersheds were most susceptible to soil erosion and sediment loss after clearcut harvesting or site preparation when the greatest amount of mineral soil was exposed and before herbaceous plants vegetate the areas. The largest single rainfall event occurred on March 20, 1985, nine months after harvesting watersheds 2-4 and five months after roller chopping watershed 2. Storm flow and peak discharge rates for all mechanical treatments exceeded rates on the untreated watershed (Table 4). Sediment losses, however, were small from all watersheds. Approximately one month after the shearing and windrowing treatment was completed on watersheds 1, 3, and 4, and nine months after the roller chopping treatment on watershed 2, storm flow, peak discharge rate, and sediment loss from a 3.4-inch rain storm (July 16, 1985) were again greate from all treated watersheds than from the undisturbed watershed. Absolute sediment loss values were low (0.5-36 lb/acre) from all watersheds. Sediment loss from site-prepared watersheds continued to decline with time.



igure 2.--Accumulated storm flow relationships between the undisturbed watershed (WS-5) and the four treated watersheds, with occurrences of clearcut harvesting (CLCU), roller chopping (ROCH), shearing and windrowing (SHWI), moderate continuous grazing (MCG), moderate rotational grazing (MRG), and pre-treatment relationships noted, Angelina National Forest, Texas, 1981-1986.

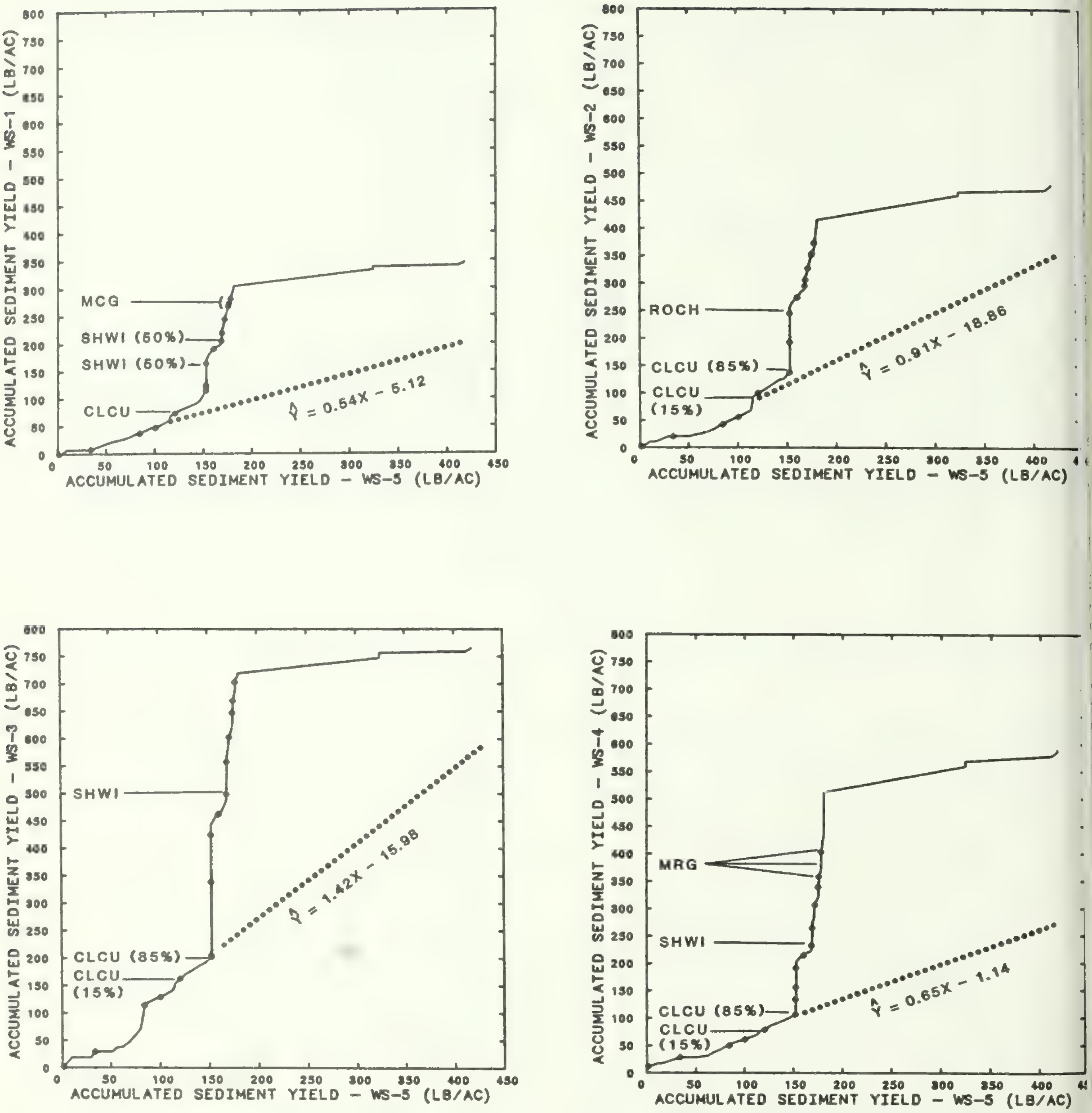


Figure 3.--Accumulated sediment loss relationships between the undisturbed watershed (WS-5) and the four treated watersheds with occurrences of clearcut harvesting (CLCU), roller chopping (ROCH), shearing and windrowing (SHWI), moderate continuous grazing (MCG), moderate rotational grazing (MRG), and pre-treatment relationships noted, Angelina National Forest, Texas, 1981-1986.

able 4.--Post-treatment (1985, 1986) storm flow, peak discharge rate and sediment loss by treatment for selected large rainfall events, Angelina National Forest, Texas

Treatment	Watershed	Storm Flow (inches)	Annual Storm Flow (percent of total)	Peak Discharge Rate (cfs)	Sediment Loss (lb/acre)	Annual Sediment Loss (percent of total)
March 20, 1985, Precipitation[1] = 2.1 in, 5.9 h duration, EI[2] = 1,952 ft-tons/ac, Maximum I_{30} = 1.1 in/h						
ndisturbed	5	0.2	5	0.4	3.2	18
hopped	2	0.9	10	3.8	4.8	6
arvested	3	1.1	8	3.9	14.0	8
arvested	4	0.9	9	3.2	2.8	3
arvested/50% Sheared	1	0.9	9	3.5	2.1	3
July 16, 1985, Precipitation = 3.4 in, 2.8 h duration, EI = 8,748 ft-tons/ac, Maximum I_{30} = 5.6 in/h						
ndisturbed	5	<0.1	2	0.5	0.5	3
hopped	2	0.8	10	10.8	11.5	15
heared	3	1.8	13	30.8	35.8	22
heared	4	1.6	15	21.6	20.0	19
heared	1	0.9	9	11.1	12.8	17
October 29, 1985, Precipitation = 3.7 in, 27 h duration, EI = 1,100 ft-tons/ac, Maximum I_{30} = 0.5 in/h						
Undisturbed	5	0.1	7	0.2	1.9	10.6
Chopped	2	2.0	24	2.2	10.2	13.4
Sheared	3	3.0	21	2.9	19.4	11.8
Sheared	4	2.4	22	2.5	9.8	9.2
Sheared	1	2.4	25	2.5	10.9	14.8
November 7, 1986, Precipitation = 2.3 in, 30 h duration, EI = 3,267 ft-tons/ac, Maximum I_{30} = 1.6 in/h						
Undisturbed	5	0.5	8	0.6	2.7	1.1
Chopped	2	1.1	7	2.2	37.7	25.1
Sheared	3	1.4	7	4.4	10.9	6.9
Sheared/Grazed, Rotation	4	1.1	7	4.6	31.8	11.6
Sheared/Grazed, Continuous	1	1.0	6	2.8	19.7	19.8
November 23, 1986, Precipitation = 8.8 in, 68 h duration, EI = 10,522 ft-tons/ac, Maximum I_{30} = 1.5 in/h						
Undisturbed	5	4.0	7	10.5	143.1	58.5
Chopped	2	6.9	44	11.6	44.8	29.8
Sheared	3	7.2	34	14.1	27.5	17.4
Sheared/Grazed, Rotation	4	6.0	37	13.1	47.3	17.2
Sheared/Grazed, Continuous	1	7.1	46	12.2	29.0	29.2

[1] Mean storm precipitation of the five watersheds.

[2] I_{30} = Maximum 30 minute intensity, EI = Erosion Index.

One week after the livestock grazing season (November 7, 1986), a 2.3 inch rain storm increased storm flow and peak discharge rate above the undisturbed watershed, but only small sediment losses (10.9-37.7 lb/acre) occurred from the treated watersheds. The largest rain storm event (8.8 inch) during the six year study occurred on November 23, 1986 after all treatments were in place and livestock grazing was completed for the season. Storm flow and peak discharge rates remained high with the greatest sediment loss (143 lb/acre) occurring from the undisturbed watershed. This was the result of bank sloughing, probably caused by rodent activity, and the large storm. Sediment loss continued to remain low from the treated watersheds. The greatest sediment loss (47 lb/acre) from the treated watersheds during this storm was from the clearcut, sheared, windrowed, and rotationally grazed watershed.

The high stocking density of the intensive rotational grazed watershed appeared to increase livestock trailing and the potential for disturbance to stream channels, thus increasing the potential sediment loss over the moderately stocked continuously grazed watershed.

SUMMARY

Undisturbed forests are generally characterized by having low storm flow and sediment loss. Large, intense storms are responsible for most of the sediment lost from both undisturbed and disturbed forest (Beasley 1979, Blackburn and others 1986, Greer 1971).

Clearcut harvesting resulted in significant increases in storm flow, peak discharge rates, and sediment loss for both small storms (storm flow not occurring from the undisturbed watershed) and large storms (storm flow occurring from the undisturbed watershed). This is mainly attributed to the removal of protective overstory vegetation which reduces evaporation and increases soil moisture available to stream flow. Harvesting may also disturb the forest floor, thus reducing infiltration rate and increasing overland flow.

For small storms roller chopping was particularly effective in reducing peak discharge rate, storm flow, and sediment loss by covering the ground with a protective layer of litter and slash, and by increasing microrelief via the roller chopper blade depressions. Shearing and windrowing, on the other hand, resulted in greater storm flow and sediment loss. The excessive surface soil disturbances from shearing, together with the movement of debris into windrows, exposed the soil to raindrop impact which breaks soil aggregates into smaller particles. These particles are easily detached and may leave the site and/or clog larger soil pores. As a result infiltration is reduced and surface runoff is increased, thus augmenting the potential for further loss of sediment.

For large storms, roller chopping and shearing/windrowing treatments resulted in greater storm flow peak discharge rate and sediment loss than clearcut harvesting. This is mainly attributed to the removal of the remaining standing vegetation which further reduced evapotranspiration and increased soil moisture available to storm flow. The benefits of the increased depression storage capacity created by roller chopping were only slightly effective in reducing storm flow and sediment loss from the larger storms. As a result, both roller chopping and shearing/windrowing treatments were similar in their response to the larger rainfall events.

Clearcut harvesting and mechanical site preparation of gentle sloping (< 8 percent) watersheds in East Texas increased storm flow, peak discharge rates, and sediment loss over undisturbed watersheds. The sediment losses from these intensively managed watersheds were within the range of sediment losses from undisturbed watersheds in the Southeast, below the range of losses from mechanical site prepared watersheds elsewhere, and well below potential losses from pasture and cropland (Yoho 1980, Loehr 1974). A study by Blackburn and others (1986) near Alto, Texas indicated that roller chopping is an effective forest soil conservation practice for watersheds having slopes up to 25 percent. Shearing and windrowing had little impact on sediment loss from gentle (< 8 percent) sloping watersheds and appear to be a sound forest soil conservation practice for gentle sloping watersheds.

Although one year's data is not enough to determine the impact of livestock grazing on forest soil and water resources, it appears that properly stocked livestock grazing has little impact on sediment loss or storm flow. However, there is a potential for increased stream channel instability and sediment losses caused by the hig stocking density of intensive rotation grazing systems.

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Assessment of Silvicultural and Grazing Treatment Impacts on Infiltration and Runoff Water Quality of Longleaf-Slash Pine Forest, Kisatchie National Forest, Louisiana

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Abstract.--The impact of intensive silviculture, extensive silviculture, moderate continuous livestock grazing and no livestock grazing on infiltration and runoff water quality were evaluated using a rainfall simulator over an 11 ft^2 plot. Study sites were located in the Vernon District of the Kisatchie National Forest, Louisiana. Overall, infiltration and runoff water quality were significantly greater from areas under extensive silviculture and no livestock grazing than from areas under intensive silviculture and livestock grazing. Although some statistical significances were observed between treatments, differences were small and no alarming decreases in infiltration or runoff water quality resulted from any of the applied treatments. This research strongly indicates that the silvicultural and livestock grazing practices applied had minimal impacts on the soil and water resources of the study area, under the prevailing climatic soil and vegetation conditions.

The Southeastern forest provides numerous natural resources important not only to the local regions but to the country as a whole. Currently, this region is producing half of the nation's wood supply, with wood demands expected to double by the year 2000, resulting in a projected 70% increase in wood production within the Southeastern region (Ursic 1975). Also, potential range forage production in the South is greater than in other range areas within the United States (Grelen 1978). Approximately 28 million cattle are utilizing this forage resource, with 14 million head being beef cows and replacement heifers. The Southeast contains 25% of all cattle and calves in the United States and 33% of all beef cows and replacement heifers. Since little is known concerning the impacts of silvicultural and livestock grazing practices on water quality, water yield or site productivity in the Southeast, it is extremely important to assess these impacts, to provide forest managers with the knowledge necessary to make sound resource management decisions.

Intensive forest harvesting and site preparation practices have been identified as causing potential declines in site productivity and as a source of non-point pollution. Harvesting and site preparation increase the potential for sediment loss by disturbing the protective surface layers of the forest floor. Compaction and destruction of surface soil structure and macropore space cause an increase in surface runoff, thus increasing the sediment production potential (Dixon 1975, Lull 1959, Moehring and Rawls 1970). Disturbing the protective vegetation and litter opens the soil to raindrop impact, which breaks soil aggregates into smaller particles. These particles are more easily detached and may leave the site in runoff, and/or may clog larger soil pores, thus reducing infiltration and increasing surface runoff (Edwards and Larson 1969). Removal of vegetation and litter also reduces resistance to overland flow and increases water velocity, which in turn increases the carrying-power of runoff (Douglass 1975).

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The long history of woodland grazing and poorly designed studies to evaluate proper livestock management has given the grazing animal a bad image in Eastern forestry (Lee 1980, Johnson 1952, Adams 1975). Livestock grazing influences an area by: 1) decreasing protection cover, thus increasing the impact of raindrops and overland flow, 2) reducing soil organic matter and soil aggregation, 3) increasing soil surface crusting, and 4) increasing runoff and erosion (Blackburn 1984).

The objective of this study was to assess the impact of intensive silviculture, extensive siviculture, continuous livestock grazing and no grazing on infiltration and runoff water quality.

STUDY AREA DESCRIPTION

The study area was located approximately 30 miles southeast of Leesville, Louisiana on the Fullerton Allotment, Vernon Ranger District, Kisatchie National Forest. Normal annual rainfall is 54.3 inches and the average annual temperature is 65.8°F. The average frost-free season is 245 days, from the end of March to mid-November. July and August are the hottest months (81.9°F), with December and January being the coldest months (51.1°F).

Gentle rolling topography, intersected by numerous drainages, characterize the area. Elevations range from 180 to 443 feet above sea level. Vegetation consists mainly of a longleaf pine (Pinus palustris) overstory and a bluestem (Andropogon sp.) and panicum (Panicum sp.) grass understory. Study site soils are of the Malbis series, which is a fine-loamy, silicous, thermic Plinthic Paleudult. Soils are deep and moderately well drained and occur on side slopes and gently sloping ridgetops.

METHODS

Study sites were sampled in June and August/September of 1982-1984, and for a final time in September of 1985. A rainfall simulator similar to the one described by Meyer and Harman (1979) was used to determine infiltration and runoff water quality over an 11 ft^2 plot. In order to reduce variability attributable to antecedent soil water content, the plots were pre-wet by applying four inches of water at a rate of four in/h from a mist-type nozzle under a plastic cone four feet above the soil. The plots were then covered with plastic to reduce evaporation. When plots were at or near field capacity (approximately 24 hours later), simulated rainfall was applied at a rate of five in/h to insure runoff from all plots. Runoff from each plot was regularly pumped into tared containers. At each 5 minute interval during the simulated rainfall event the cumulative runoff was weighed and mean infiltration rate (in/h) was calculated by determining the difference between applied rainfall and the quantity of runoff. Upon termination of each simulated rainfall event, a thoroughly agitated one quart subsample and an 18 ounce whirl-pac subsample were collected. The one quart subsample was filtered through a #1 Whatman filter paper, dried at 221°F for 24 hrs and weighed, converted to sediment production in lb/acre, and used as an index of erosion. The 18 ounce whirl-pac sample was frozen and later analyzed for part per billion (ppb) concentrations of total unfiltered nitrogen and total phosphates.

The study pastures underwent one of two silvicultural management practices, i.e. seedtree harvesting or thinning. Seedtree harvesting was considered an intensive silvicultural practices and involved the removal of most trees, leaving 17 to 25 ft^2 basal area per acre. Trees were left as a seed source and were chosen based on phenotype, spacing and cone producing characteristics. After harvesting, the areas were site prepared using a drum chopper or rake harrow (a railroad tie with spikes 3 to 4 inches long dragged behind a tractor) and broadcast-burned to remove extraneous stems and debris. Once pine seedlings were established, all remaining seed trees were harvested. Forest thinning was treated as an extensive silvicultural practice with minimal management conducted over a large area. Thinning was done to improve growth of remaining pines, to enhance browse and mast for wildlife production and to improve herbaceous production for livestock by removing part of the surrounding overstory. One third of the thinned area was prescribed-burned every year in a rotational sequence to remove excessive undergrowth and reduce fuel loads. Silvicultural study sites were located with seed tree harvest and thinning treatments adjacent to each other. Treatment dates for each study site are summarized in Table 1.

Table 1.--Study site silvicultural treatment schedules, Vernon District, Kisatchie National Forest, Louisiana

Study Site	Seedtree harvest	Thinning
1	February 1980	March 1978
2	February 1982	March 1978
3	February 1980	March 1980
4	February 1980	March 1980
5	February 1977	March 1980
6	February 1977	March 1980

Prior to the study from 1967 to 1977, cattle had free access to the allotment, and stocking rates averaged 3.1 acre/animal unit month (ac/aum). In 1977 the allotment was cross-fenced into four pastures; however, grazing sequences were not initiated until 1981. Six study sites were located, with two sites in each of three pastures varying in size from 1322 to 1668 acres (Pearson and others 1987). Four study sites were located in pastures grazed seven months continuously from April 1 to October 31. The two remaining study sites were located in a pasture grazed continuously yearlong. All study sites were grazed at a stocking rate of 3.5 to 4.0 ac/aum (Pearson and others 1987). Livestock exclosures were constructed in 1982; however, construction was not completed until after the first sampling period and just prior to the second sampling period. For this reason both sampling periods in 1982 were treated as grazed conditions.

Initially three grazing treatments (seasonal continuous grazing, yearlong continuous grazing and no grazing) were analyzed for statistical differences. In the final analyses, however, seasonal and yearlong continous grazing treatments were analyzed together as one grazing treatment. This was done for three reasons: 1) no statistical evidence was found to indicate a significant difference between the two grazing treatments, 2) Forest Service stocking rates were based on ac/aum, which includes a time factor to correct stocking rates, appropriately, for seasonal or yearlong use, and 3) separation of the two grazing treatments only decreased the degrees of freedom and weakened the strength of the statistical analyses.

Experimental treatments evaluated were: seedtree harvesting (intensive silvicultural); forest thinning (extensive silviculture); continuous livestock grazing; and no livestock grazing. A stripping or crisscross analysis of variance was used to test for treatment differences by sample date and for all sample dates combined. Significant differences were discussed at the 95 percent level of confidence. Since the two silvicultural treatments were not found to be statistically different at the two grazing treatment levels, treatments were separated and significant differences pertain only to silvicultural means or grazing means. For each sample date, 48 individual plots were sampled when six replications and two subsamples were employed (2 grazing treatments x 2 silvicultural treatments x 6 replications x 2 subsamples).

RESULTS AND DISCUSSION

Silviculture

Infiltration rate means for extensive silviculture versus intensive silviculture were not found to be statistically different for any of the individual sampling dates (table 2). Individual sampling dates all had higher infiltration rate means for extensive silviculture, which contributed to the significantly higher combined mean across all sampling dates. Combined infiltration rate means were 2.05 in/h for extensive silviculture and 1.69 in/h for intensive silviculture.

Sediment production was somewhat variable across sampling dates, but, in general, more sediment production occurred from intensive silviculture than from extensive silviculture (table 3). The intensive silviculture mean of August 1984 (186.7 lb/ac), together with the intensive silviculture combined overall mean (141.6 lb/ac) were found to be significantly greater than respective means (96.8 and 102.7 lb/ac) from extensive silviculture.

Table 2.--Mean infiltration rate (in/h) by sampling date and for all sample dates combined, Vernon District, Kisatchie National Forest, Louisiana

Sample Date	Intensive Silviculture	Extensive Silviculture	Livestock Grazing	No Livestock Grazing
June 1982	1.73a[1]	1.89a	1.81	--[2]
Sept. 1982	1.73a	1.95a	1.8	--
June 1983	1.75a	2.30a	1.86a	2.18a
Aug. 1983	1.47a	1.63a	1.56a	1.54a
June 1984	1.80a	2.13a	1.77a	2.15a
Aug. 1984	1.39a	2.00a	1.68a	1.71a
Sept. 1985	1.99a	2.30a	1.80b	2.48a
Combined Mean	1.69b	2.05a	1.76b	2.01a

[1] Silviculture or grazing treatment means by sample date and combined across all sample dates, followed by the same letter, are not significantly different, P<.05.

[2] No sample date treatment mean.

Table 3.--Mean sediment production (lb/ac) by sampling date and for all sample dates combined, Vernon District, Kisatchie National Forest, Louisiana

Sample Date	Intensive Silviculture	Extensive Silviculture	Livestock Grazing	No Livestock Grazing
June 1982	44.5a[1]	48.3a	46.4	--[2]
Sept. 1982	278.7a	244.8a	261.8	--
June 1983	64.7a	73.6a	77.1a	61.2a
Aug. 1983	199.1a	142.4a	218.5a	122.2b
June 1984	42.7a	61.8a	56.6a	47.9a
Aug. 1984	186.7a	96.8b	124.6a	158.9a
Sept. 1985	186.3a	61.1a	178.4a	74.5b
Combined Mean	141.6a	102.7b	138.8a	92.8b

[1] Silviculture or grazing treatment means by sample date and combined across all sample dates, followed by the same letter, are not significantly different, P<.05.

[2] No sample date treatment means.

Individual sampling date unfiltered total nitrogen concentration means were found to be significantly higher only from intensive silviculture (2775 ppb) and not significantly higher from extensive silviculture (1327 ppb) for the August 1984 sample date (table 4). Combined means across all sample dates were found to be significantly higher from intensive silviculture (1777 ppb) than from extensive silviculture (1403 ppb). Overall, intensive silviculture resulted in higher runoff levels of unfiltered total nitrogen.

Total phosphate concentration means were consistently higher from intensive silviculture across individual sampling dates (table 5). The individual sampling date of August 1984, and the combined mean across sample dates, were found to have significantly higher total phosphate concentrations from intensive silviculture. Total phosphate means were 233 and 209 ppb from intensive silviculture, and 136 and 178 ppb from extensive silviculture from August 1984 and combined sample dates, respectively.

Table 4.--Mean total unfiltered nitrogen concentrations (ppb) by sample date and for all sample dates combined, Vernon District, Kisatchie National Forest, Louisiana

Sample Date	Intensive Silviculture	Extensive Silviculture	Livestock Grazing	No Livestock Grazing
June 1982	--[1]	--	--	--
Sept. 1982	980a[2]	1227a	1103	--
June 1983	1204a	1640a	1519a	1324a
Aug. 1983	3112a	2227a	2767a	2616a
June 1984	1691a	1558a	1677a	1571a
Aug. 1984	2775a	1327b	2401a	1632b
Sept. 1985	1243a	694a	1123a	813a
Combined Mean	1777a	1403b	1643a	1514b

[1] No sample date treatment mean.

[2] Silviculture or grazing treatment means by sample date and combined across all sample dates, followed by the same letter, are not significantly different, P<.05.

Table 5.--Mean total phosphate concentration means (ppb) by sampling date and for all sample dates combined, Vernon District, Kisatchie National Forest, Louisiana.

Sample Date	Intensive Silviculture	Extensive Silviculture	Livestock Grazing	No Livestock Grazing
June 1982	--[1]	--	--	--
Sept. 1982	[illegible]a[2]	424a	413	--
June 1983	136a	140a	148a	128a
Aug. 1983	166a	172a	176a	163a
June 1984	136a	98a	117a	116a
Aug. 1984	233a	136b	178a	196a
Sept. 1985	189a	111a	177a	123a
Combined Mean	209a	178b	229a	144a

[1] No sample date treatment means.

[2] Silviculture or grazing treatment means by sample date and combined across all sample dates, followed by the same letter, are not significantly different, P<.05.

In general, intensive silvicultural treatments displayed a trend of lower infiltration rates and decreased runoff water quality when compared to extensive silvicultural treatments. Runoff water quality appears to follow closely with infiltration, in that the larger treatment differences in individual sampling date infiltration rates were also the dates with larger runoff water quality differences between treatments. The lower infiltration rates and runoff water quality resulting from intensive silviculture are mainly attributed to the surface soil disturbances caused by clearcutting and site preparation, and to the subsequent removal of protective surface layers of vegetation and litter.

Grazing

For individual sample dates, the September 1985 sample period was the only date where mean infiltration rate was significantly higher for non-grazed areas than for grazed areas (table 2). The combined infiltration rate mean for the non-grazed areas was 2.01 in/hr and was significantly higher than the mean of 1.76 in/hr for the grazed areas.

Mean sediment production was significantl greater from the grazed areas than from the non grazed areas for August 1983 and September 198 (table 3). When sample dates were observed over time, the combined sediment production mean from non-grazed areas was significantly lower than from grazed areas.

Total unfiltered nitrogen concentration means for individual sample dates were consistently higher from the grazed areas than from the non-grazed areas, which contributed to the significant difference found for combined means (table 4). Although only a small difference was apparent between the combined total nitrogen mean of 1643 ppb for grazed areas and 1514 ppb for non-grazed areas, differences were nonetheless significant. The August 1984 sampling date was the only individual sampling date with significantly higher total nitrogen concentrations in runoff from grazed areas (2401 ppb) than from non-grazed areas (1632 ppb).

Total phosphate concentration means were low and no significant differences were found between grazing treatments (table 5). Phosphate concentrations in runoff were generally higher from the grazed areas; however, differences between treatments were not significant. The combined total phosphate mean across sample dates was 229 ppb for grazed areas and 144 ppb for non-grazed areas.

Generally, a trend existed for lower infiltration and decreased runoff water quality from grazed areas than from non-grazed areas. As with silvicultural responses, runoff water quality followed closely with infiltration, in that sample dates with large treatment differences in infiltration rates usually had corresponding treatment differences in runoff water quality. Influences of livestock grazing on infiltration and runoff water quality were probably mainly a result of the removal of protective vegetative cover and surface soil disturbances from trampling.

SUMMARY

Infiltration rates and runoff water quality displayed a pattern of decreasing infiltration and increasing sediment production as the seasons progressed from spring to fall. This was mainly attributed to freezing and thawing, soil drying, microorganism activity and soil surface sealing from raindrop impact, all occurring as the seasons progress (Bertoni and others 1958, Musgrave 1955).

Overall, infiltration and runoff water

quality were significantly greater from areas under extensive silviculture or no livestock grazing, than from areas under intensive silviculture or continuous livestock grazing. It is important to note that although significant decreases in infiltration and runoff water quality resulted from intensive silviculture and continuous grazing, these decreases were small and did not represent any drastic changes to the soil and water resources of the study area. The primary impacts attributable to silvicultural or grazing treatments are predominantly related to the degree of disturbance resulting from either practice.

The decrease in infiltration and runoff water quality following intensive silviculture is primarily due to the removal of protective vegetation and the disturbances in surface soil conditions which invariably follow intensive harvesting and site preparation operations. Resulting decreases in infiltration and runoff water quality are short-lived, and diminish as revegetation and site recovery occur.

Decreased infiltration and runoff water quality resulting from livestock grazing are mainly due to the removal of protective plant cover and to surface soil trampling. These effects cannot be completely eliminated without eliminating grazing of livestock and wildlife, altogether. However, the adverse effects of livestock grazing can be minimized with wise and judicious livestock management. This means that heavy continuous grazing should be avoided and moderate stocking rates or use should be maintained. Since very little research has been conducted on the influence of livestock grazing, particularly specialized systems, on the soil and water resources of the Southern pine forest, the potential impacts livestock may have are poorly understood. Thus, it is important that research be conducted to determine the best or most optimum level of livestock grazing, in conjunction with various silvicultural practices, in order to successfully integrate the multiple-use concept, vital to forest management objectives.

This research strongly indicates that, under the prevailing climatic, soil and vegetation conditions, the silvicultural and livestock grazing practices applied had minimal impact on soil and water resources of the study area.

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Sediment Production from Long-term Burning of a Longleaf Pine-Bluestem Association

J. P. Dobrowolski, W. H. Blackburn, and H. E. Grelen

Abstract.--A mobile, spray-nozzle type rainfall simulator (2.9, 4.4, and 5.0 in/hr for 45 min) was used to determine long-term effects of prescribed burning on surface cover and sediment production from a longleaf pine/bluestem association in Louisiana. Treatments represented biennially-applied winter, spring, or summer burns on an upland sandy loam site; and annual winter or spring, and biennial winter or spring burns on a bottomland silt loam site with associated unburned controls. Immediate effects of burning were to remove soil surface cover, exposing soil to raindrop impacts. Burning the sandy loam site during winter and spring significantly increased sediment production from 10.76 ft^2 rainfall simulation plots and exposed mineral soil throughout the treatment-year growing season when compared to unburned control plots. Rapid recovery of the herbaceous understory reduced differences among treatments by growing season end and stabilized sediment production within ten months. Effects of long-term prescribed burning of sandy loam and silt loam sites did not persistently increase sediment production when compared to unburned plots one and two years post-treatment, respectively.

INTRODUCTION

Fire is one of the most important ecological factors in the longleaf pine (Pinus palustris Mill.) region. Much valid evidence indicates that fire is the main factor responsible for perpetuation and maintenance of longleaf pine in its typical forest stands (Garren 1943). In the longleaf pine type, most wildfires do not generally create conditions as in other timber types. With rapid decay limiting total fuel buildup, most fires remain at the surface, with longleaf pine exhibiting particularly effective fire resistance (Heyward 1938).

Recognition of these conditions forms the basis of prescribed burning, acknowledged by silviculturalists as an accepted management technique in the southern pine forest region (Bruce 1947). Burning, whether prescribed or accidental, may affect the watershed through removal of the protective soil cover and alteration of soil physical and chemical properties. With regard to its frequency and intensity, burning has the potential to accelerate erosion, increase overland flow, decrease water-holding capacity, reduce soil fertility, and degrade stream water quality.

Intense research interest has been focused upon the influence of burning on hydrologic parameters, particularly in areas with severe flooding potential or where the maintenance of long-term site productivity is essential. Much work has been published on the effects of fire on soil (Burns 1952, Wells and others 1979), water (Tiedemann and others 1979), shifts in vegetative composition (Lotan and others 1981), and ecosystem

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function (Ahlgren and Ahlgren 1960). Numerous studies have been confined to either comparison of frequent burning with complete fire protection or the observation of the effects of a single severe fire. Study site specificity and conflicting results tend to inhibit the making of generalized inferences. In many cases, the effects of burning have been confounded with other silvicultural and/or range improvement practices. Few research projects have dealt with the effects of long-term maintenance burning seasonally applied on sediment production and surface cover conditions, exclusive of other treatments.

Sediment production rates, contingent upon fire intensity, soil properties, and surface cover conditions, may vary following a fire. Sediment losses from undisturbed watersheds in southern and southeastern forests are inconsequential (Yoho 1980). However, Blackburn and others (1986) found sheared, windrowed, and burned watersheds in east Texas to produce more sediment than roller-chopped and burned and undisturbed watersheds four years after treatment. Sediment losses following these site preparation techniques were significantly different between treatments, but were small and below Soil Conservation Service tolerable levels. Pye and Vitousek (1985) showed erosion on chop and burn plots to be negligible under loblolly pine.

Small but significant increases in suspended sediment occurred from maximum disturbance and site preparation consisting of tree-length harvesting, slash burning, windrowing, soil bedding, and machine planting of poorly drained pine flatwoods of northcentral Florida (Riekerk 1985). Sediment production from treated watersheds was not significant during the first post-treatment year.

Lear and others (1985) studying soil and nutrient export from clearcut loblolly watersheds found two preharvest, low-intensity prescribed fires had no effect on discharge water quality. Harvesting after the third prescribed fire significantly increased sediment concentration and export. Treatment differences in sediment yield were greater on clearcut, crushed, burned, and contour ripped when compared to undisturbed watersheds in the Ouachita Mountains of eastern Oklahoma during the first through third, but not the fourth post-treatment years (Miller 1984). The overall effects of harvest practices and site preparation on suspended sediment levels was small and short-lived, however.

The objective of this study was to determine the treatment-year and long-term effects of biennial prescribed burning at three seasonsonsediment production and surfacecover conditions in a longleaf pine/bluestem association.

STUDY AREA

Field research was conducted in a 250 ac stand of longleaf pine on the Palustris Experimental Forest approximately 33 mi south of Alexandria, Lousiana. The research location is typical of longleaf pine/bluestem (*Schizachyrium* spp.) sites. Elevation of the study site varies from 130 to 295 ft with slopes ranging from 1 to 30 percent. The area has a humid, subtropical climate with a mean annual temperature of 77°F with an average growing season of 300 days. The average annual rainfall is 57 in with growing season peaks in April, May, and July. Study site soils have predominantly sandy loam surface and clay loam subsurface horizons developed on Columbian deposits laid down during the Quaterna period of the Pleistocene. Little forest floor i present; instead there is a vigorous ground cover composed largely of perennial grasses.

Sandy loam unit

In 1962 sixteen 10,000 ft^2 plots were established on an ungrazed site representative of the longleaf pine/bluestem range. The site gradient ranged from dry ridgetop to moist lower slope (Grelen and Epps 1967, Grelen 1975) dominated by the Ruston soil series, which is a member of the fine-loamy, siliceous, thermic family of Typic Paleudults. It is classified as a Woodland Suitability Group 2o1, rangesite 4, with a fine sandy loam topsoil of about 11 in. Overstory vegetation consists of longleaf pine with a relative abundance of southern waxmyrtle (*Myrica cerifera* L.), shining sumac (*Rhus copallina* L.), American beautyberry (*Callicarpa americana* L.), and blackjack oak (*Quercus marilandica* Muenchh.). Herbaceous dominants include pinehill bluestem (*Schizachyrium scoparium* v. *divergens* Nash), slender bluestem (*Schizachyrium tenerum* Nees), and broomsedge bluestem (*Andropogon virginicus* L.).

Silt loam unit

In 1973 fifteen 10,000 ft^2 plots were established on a second ungrazed area with little site gradient. Soils consisted of a poorly drained Beauregarde silt loam, a member of the fine-silty, siliceous thermic family of Plinthaquic Paleudults. This series is classified as a Woodland Suitability Group 2w8, rangesite 2, with low permeability and plinthite in the subsurface horizons. Overstory dominants included waxmyrtle, blackjack oak, sweetgum (*Liquidamber styraciflua* L.), black tupelo (*Nyssa sylvatica* Marsh.), and other moist-site hardwoods. Bluestems dominate the understory, with scattered panicum species (*Panicum* spp. and *Dicanthelium* spp. Gould) and paspalums (*Paspalum* spp.)

METHODS AND PROCEDURES

Treatments

The upland sandy loam site has remained ungrazed since 1955 (Grelen 1975). In 1962, all pines, hardwoods, and shrubs were removed from study plots. Initially, four treatments consisting of annual burns in winter (March 1), spring (May 1), summer (July 15), and mechanical removal of vegetation were installed in a randomized block design. Beginning in 1964, burning treatments were scheduled biennially, and the summer burning date changed to July 1. Mechanical removal of vegetation was discontinued after March 1963 and these unburned plots constituted the controls. Treated plots were burned in 1982 as part of the normal biennial cycle. Standing fine fuel was clipped and mulch was collected from eight randomly located 2.7 ft^2 plots prior to each burning date (Table 1). Fire temperatures were approximated using "Tempil" tablets set at 4 in aboveground and at the mineral soil surface (Silen 1956).

In 1968 loblolly pines (*Pinus taeda* L.) were girdled prior to direct seeding of longleaf pines on the silt loam unit. The area had been burned and grazed in 1970. During 1973 three replications of annual and biennial March 1 and May 1 burning treatments were installed in a completely randomized design. Since 1973, all fires have been set within four days of target date (Grelen 1978). All fires on both units were burned with headfires except when hazardous burning conditions made backfires necessary. In 1980 annual winter and spring burning treatments were reassigned as triennial burns, thereby precluding treatment during 1982.

Rainfall Simulation

Rainfall simulation sample plots were superimposed on the burning treatments of the sandy loam unit treated in 1982. Within each burning replication eight randomly assigned subplots 25 ft by 50 ft were delineated to represent sampling dates for simulated rainfall. For a specific date within each subplot two 10.76 ft^2 simulated rainfall/runoff plots was placed at random unless severely restricted by access or the occurrence of macropores. It was assumed that sampling during the treatment year would allow evaluation of short-term effects, while 1983 sampling dates would permit quantification of the effects of long-term biennial burning. Dates of prescribed burning treatment and watershed evaluation were as follows:

Table 1.--Fire and fuel variables during the 1982 prescribed burning treatment in a longleaf pine/pinehill bluestem association near Alexandria, Louisiana

		Mean fuel load (lb/ac)[1]			Fire temperature (°F)		
Season	Replication	Grass	Forb	Mulch	Soil surface	6 in above-ground	Mean fire speed (sec/ft)
Winter (March 1)	A	2402	181	1948	500	500	13
	B	1324	206	6143	500	600	18
	C	802	207	5100	300	600	3
	D	1351	353	2332	600	600	24
Spring (May 3)	A	1434	773	11135	400	600	17
	B	1172	38	14074	500	600	31
	C	1604	22	9825	500	600	16
	D	1558	210	9296	200	700	33
Summer (July 1)	A	4092	101	1546	300	600	13
	B	3192	74	9706	300	500	20
	C	1920	74	13341	200	500	22
	D	4547	273	9628	150	300	27

[1] Winter fuel loads are estimates based upon aboveground standing crop sampling 1 year after treatment.

Treatment	Evaluation date Pre-burn	 Post-burn
Sandy loam		
Winter burn (March 1982)	None	4-30-82[1/]
Spring burn (May 1982)	4-30-82	5-30-82
Summer burn (July 1982)	5-30-82	7-15-82
None		8-15-82
None		10-15-82
Longterm effects		5-30-83
Longterm effects		9-15-83
Silt loam		
Longterm effects	None	6-07-82
Longterm effects	None	10-20-82

[1/] Each date represents evaluation of all replications of all treaments and unburned control plots.

Selected dates incorporate seasonal differences (i.e. growing season versus dormancy). Rainfall/runoff plots were similarly superimposed on the treatment plots of the silt loam unit. Sampling dates represented an attempt to elicit long-term burning effects for the annual and biennial treatments incorporating seasonal differences.

A multiple-intensity rainfall simulator produced rainfall at three intensities over a 45 min storm duration to the fixed area rainfall simulation plots (Meyer and Harmon 1979). Intensities included 2.9 in/h, 4.4 in/h and 5.0 in/h representing 25-year, 35-year, and 50-year return period storms, respectively. Rainfall simulation plots were prewet with 37 gal of water using an elliptical mist-type nozzle sprinkler to standardize antecedent soil moisture conditions.

Suspended sediment was determined by vaccum-filtering a 0.3 gal subsample through a No. 1 Whatman filter, and oven-drying at 221°F for 24 h. The sample was weighed, runoff volume-weighted, converted to sediment yield in lb/ac, and used as an index of sheet erosion (Blackburn 1975).

Ocular estimates of plot cover were made using a 10.76 ft^2 frame gridded into 0.11 ft^2 squares. Surface cover consisted of shrubs (less than 3.3 ft height), grasses, forbs, litter, and bare ground. Standing crop was measured by clipping grasses, low shrubs, and forbs at the mineral soil surface. Vegetative standing crop and raked surface litter was air-dried at 140°F for 48 h and weighed.

Antecedent soil moisture and soil bulk density were determined for each rainfall simulation plot at 2 and 4 in depths utilizing the gravimetric and core methods, respectively (Black 1965). Surface soil samples were collected following rainfall simulation for laboratory analysis of particle size distributio (Bouycoucos 1962), aggregate stability, and percent organic matter (Black 1965).

Small plot characteristics and sediment production residual mean squares were tested for skewness and kurtosis (Box and others 1978). Where required, Log_{10}, reciprocal, or reciprocal square root transformations were applied to satisfy the assumption of normality required for the statistical analyses used in this study. An analysis of variance (ANOV) was applied to sediment production data for each treatment to elicit possible differences among treatment mean (P<0.05). Where appropriate, Student-Newman-Keu (SNK) mean separation test for equal cell sizes was applied to the data. Simple linear correlation analysis was employed to determine th degree of association of measured variables with sediment production. Multiple regression, utilizing a modified forward stepwise technique, was applied to specify the best linear variable combination influencing sediment production.

RESULTS AND DISCUSSION

Sandy Loam Unit

Surface Cover Responses.--Short- and long-term vegetation responses to burning have shown consistent shifts in dominance to resistant longleaf pine and herbaceous species on the sandy loam unit (Grelen 1975). Burning has effectively reduced growth of susceptible noncommercial and commercial woody plants. Restriction of prescribed burning resulted in a dense overstory of shrub and tree species with concomitant heavy litter component. This overstory restricted herbaceous growth to scattered canopy openings. Maintenance burning stimulated production of an herbaceous understory in all treated plots. Scattered longleaf pines provided inherent variation in the degree of litter accumulation on burned plots.

Vegetal and mulch surface cover alleviates raindrop impact on bare mineral soil, thereby reducing soil aggregate breakdown, slaking, suspension and transport of soil particles. These cover conditions can be integrated into the percent exposed bare soil (Table 2) which can be used as an index to the potential for raindrop impact effects. Bare soil exposure from winter burning during 1982 was significant for four months post-treatment when compared to unburned controls. Spring burning treatments produced 71.4 percent bare soil exposure during the first month after burning, and contained significantly more exposed bare soil through August, 1982. Similarly, summer burning reduced ground cover to 52.4 percent, exposing bare soil through August, 1982. End-of-growing season sampling (October 1982) showed evidence for considerable vegetation and mulch cover response, resulting in a reduction of exposed mineral soil to undisturbed levels. Bare soil exposure one year post-treatment was similar to unburned control plots.

Table 2.--Mean bare ground (%) by burning treatment and sample date, sandy loam site in a longleaf pine/pinehill bluestem association near Alexandria, Louisiana

	Burning treatments[1]							
	Winter March 1, 1982		Spring May 3, 1982		Summer July 1, 1982		Unburned control	
Evaluation dates	$\bar{X}$	$S_{\bar{X}}$	$\bar{X}$	$S_{\bar{X}}$	$\bar{X}$	$S_{\bar{X}}$	$\bar{X}$	$S_{\bar{X}}$
April 30, 1982	32.50^{a}	5.90	0.12^{b}	0.12	1.75^{b}	1.22	0.88^{b}	0.64
May 30, 1982	33.12^{b}	5.76	71.38^{a}	7.10	5.38^{c}	2.21	3.00^{c}	1.00
July 15, 1982	21.00^{b}	3.62	31.75^{b}	5.09	48.62^{a}	7.84	0.25^{c}	0.16
August 15, 1982	8.12^{b}	2.31	15.62^{a}	2.74	17.12^{a}	2.72	2.25^{b}	1.61
October 15, 1982	5.50^{a}	3.52	9.25^{a}	2.62	6.62^{a}	1.78	0.25^{a}	0.25
May 30, 1983	4.50^{a}	2.28	2.75^{a}	1.52	4.38^{a}	0.65	3.12^{a}	0.91
September 15, 1983	3.75^{ab}	1.11	2.50^{b}	0.33	5.38^{a}	1.15	1.75^{b}	0.53

[1] Means followed by the same letter within each row are not significantly different ($P<0.05$) according to analysis of variance and Student-Newman-Keuls multiple range test.

Relative soil exposure rates from seasonal burning have implications for management of a sandy loam site. Winter-burned treatments had exposed mineral soil during winter and spring precipitation periods prior to spring vegetative regrowth. The potential for raindrop impact-induced sediment transport from intensive storm events existed during this time. Spring burning exposed mineral soil for a shorter period before spring and summer regrowth compensated for treatment effects. Summer burning exposed mineral soil for the least amount of time, but eliminated longleaf pine over the long-term (Grelen 1975). Mineral soil exposure was checked by vegetative regrowth on all treated plots by growing season end. This study provided no evidence to support perpetual changes in mineral soil exposure resulting from biennial burning of the sandy loam unit.

Sediment Production.--Sediment production in runoff from rainfall simulator plots was significantly greater after the 1982 winter and spring burns when compared to unburned plots (Table 3). By the end of the 1982 growing season, mean sediment production from these treatments was elevated but not significantly greater than sediment yielded from unburned controls.

Sediment output from treatment-year summer burning was lower relative to spring- or winter-burned plots. The summer burn, which occurred under relatively moist conditions (0.7 in of precipitation during the previous week), produced sediment at levels similar to unburned controls during the first post-treatment month.

During the 1983 sampling period, no difference in sediment production was observed between treatments. Analysis of covariance, using antecedent soil moisture as covariable, did not control additional variability to the point of altering ANOV results.

Increased sediment production immediately after a burning treatment corresponds to the findings of Roundy and others (1978), Ueckert and others (1978), and Knight and others (1983). Removal of the heavy litter load through burning tended to stimulate grass and forb production. This stimulation response observed in 1983, seemed to compensate for the lack of a protective mulch cover.

Predicated upon the sediment production data from burned plots, there may be no significant differences in sediment transport compared to unburned controls within ten months after treatment. Results show an absence of long-term changes in sediment production, and resiliency of a longleaf pine site to perturbation by biennial burning. Accelerated sediment movement immediately after burning appears short-lived and follows the degree of mineral soil exposure.

Factors Influencing Sediment Production.--Rainfall simulation plot variables that exercised the greatest influence on sediment production were percent of bare ground exposed (r=0.43), grass cover (r=-0.46), grass standing crop (r=-0.44), litter cover (r=-0.42), total surface sand (r=-0.44), surface silt (r=0.47), during the 1982 treatment year. In 1983, physical soil parameters antecedent soil moisture at the 2 and 4 in depths ($r=0.621$ and $r=0.682$ respectively), 2 in bulk density ($r=0.57$), surface silt ($r=0.65$), and surface clay ($r=0.42$) were important. Surface cover variables appeared to influence sediment as a result of removal by burning. In the post-treatment year, vegetation had returned and physical soil variables replaced cover variables in importance, accounting for up to 46 percent of the variation in sediment production. The importance of antecedent moisture indicates inconsistent prewetting of rainfall simulation plots.

Predictive equations with sediment production as dependent variable were determined by stepwise multiple regression analysis ($P<0.15$). These predictive models were used to provide insight into probable causative relationships relative to sediment production. Regressor variables have been defined as follows:

Number	Variable	Unit of measure
Y1	Sediment production	lb/ac
X1, X2	Bulk density (2 in, 4 in)	lb/in^3
X3, X4	Soil moisture	%
X5	Organic matter content	%
X6	Aggregate stability	%
X7	Total sand	%
X8	>0.08 in fraction	%
X9	0.04-0.08 in fraction	%
X10	0.02-0.04 in fraction	%
X11	0.01-0.02 in fraction	%
X12	0.008-0.01 in fraction	%
X13	>0.008 in fraction	%
X14	Total clay	%
X15	Total silt	%
X16	Grass cover	%
X17	Forb cover	%
X18	Litter cover	%
X19	Bare ground cover	%
X20	Grass standing crop	lb/ac
X21	Forb standing crop	lb/ac
X22	Litter accumulation	lb/ac
X23	Depth to clay loam	in

Significant variables in the regression equations for sediment production reflected soil profile factors or soil cover conditions that resulted from either burning treatments or from inherent, preburn differences among treatments. Fire temperatures recorded during treatment suggested that burning regardless of season, primarily affected surface litter and standing crop, but may have been too cool at the surface to produce physical soil changes (DeBano and others 1977).

The lack of protective cover was important in predicting sediment production in runoff after burning (Table 4). Percent of bare soil exposed (X19) to the impact of raindrops provided one of the principal predictive variables for suspended sediment during treatment-year and 1983 sampling periods. Other consistently important variables included 2 in bulk density (X1), percent grass cover (X16), and surface silt (X15).

Silt Loam Unit

Surface Cover Response.--Prescribed burni whether annual or biennial selectively removed broadleaf woody species and susceptible conife Restriction of burning on the silt loam unit produced a closed canopy of small diameter tree (Grelen 1978). At the time of surface cover an sediment production evaluation, two years had elapsed since the last burning treatment. Percent bare ground exposed was not significant different among treatment plots when sampled during the 1982 inactive year in the prescribed burning cycle (Table 5). These results provide no evidence for perpetually greater exposed soi as a result of annual or biennial burning treatments.

Sediment Production.--Sediment yield from simulated rainfall plots was not increased as t result of any prescribed burning treatment on this unit (Table 6). A non-significant trend f greater sediment occurred on the unburned plots during both sampling periods. These plots tend to saturate and float off considerable suspende organic material mixed with mineral sediment. Additional error control using >0.08 in sand fraction as a covariate did not improve the detection of treatment differences. Although considered erodible, results showed the Beauregarde silt loam unit was not likely to yield substantial sediment on level terrain two years post-treatment.

Factors Influencing Sediment Production. The >0.08 in sand fraction was correlated but inversely proportional to sediment production ($r=0.44$). The presence of large-diameter sand grains in the surface horizon would promote infiltration at the expense of runoff-transporte sediment. No other rainfall simulation plot variables were correlated with suspended sediment.

Litter accumulation (X22) associated with unburned control plots was important in predicting sediment production from the silt loa unit (Table 7). Surface texture variables total silt (X15) and sand fractions (X8, X11) may have affected sediment transport by influencing runoff, or altering the puddling efficiency of the surface horizon.

SUMMARY

Tiedemann and others (1979) and Glendening and others (1961) have reported sediment yield increases of ten and two hundred-fold, respectively, following western wildfire on stee slopes with slow vegetative cover response. In contrast, southern and southeastern pine forest are extremely resilient environments. Frequent prescribed burning has reduced the incidence of wildfire, slopes are rolling to level, and soil-protecting vegetation recovers quickly. Although the southern forest has a great potential for soil loss from intensive storm events, this resiliency results in short-lived effects and

Table 3.--Mean sediment production (lb/ac) from 10.76 ft rainfall simulation plots, initially at field capacity, sandy loam site initially in a longleaf pine/pinehill bluestem association near Alexandria Louisiana

	Burning treatments[1][2]							
	Winter March 1, 1982		Spring May 3, 1982		Summer July 1, 1982		Unburned control	
Evaluation dates	X	S_X	X	S_X	X	S_X	X	S_X
April 30, 1982	$181.38^{a(a)}$	63.28	$43.36^{b(b)}$	22.32	$24.60^{b(b)}$	10.04	$72.84^{b(b)}$	39.96
May 30, 1982	$191.46^{a(a)}$	52.08	$355.53^{a(a)}$	210.86	$45.32^{b(b)}$	12.66	$83.42^{b(b)}$	25.64
July 15, 1982	$63.72^{a(a)}$	21.20	$270.23^{a(a)}$	136.46	$161.24^{a(a)}$	49.13	$99.31^{a(a)}$	50.72
August 15, 1982	$1625.37^{a(a)}$	588.82	$1424.40^{a(a)}$	219.31	$984.29^{ab(ab)}$	238.75	$505.80^{b(b)}$	159.40
October 15, 1982	$1819.94^{a(a)}$	433.35	$1762.97^{a(a)}$	252.30	$1077.54^{a(a)}$	508.37	$802.40^{a(a)}$	290.35
May 30, 1983	$196.77^{a(a)}$	54.54	$168.50^{a(a)}$	54.20	$196.25^{a(a)}$	67.30	$148.55^{a(a)}$	52.16
September 15, 1983	$238.95^{a(a)}$	132.62	$161.96^{a(a)}$	33.11	$155.10^{a(a)}$	64.89	$125.74^{a(a)}$	42.55

[1] Means followed by the same letter within each row are not significantly different ($P<0.05$) according to analysis of variance and Student-Newman Keuls multiple range test.

[2] Means followed by the same letter in parentheses within each row are not significantly different at $P<0.05$) according to analysis of covariance, antecedent soil moisture (2 in depth) as a covariate, and Student-Newman-Keuls multiple range test.

Table 4.--Sediment production regression models by sampling date with all treatments combined, sandy loam site in a longleaf pine/pinehill bluestem association near Alexandria, Louisiana

Sampling date	Regression equation[1]	Coefficient of determination (R^2)
April 30, 1982	$Y = -2.7448 + 0.0685(X19)^2 + 0.0996(X15) + 30.8482(X23)$	0.543
May 30, 1982	$Y = 6.8322 - 0.0188(X16) - 2.9569(X8)$	0.208
July 15, 1982	$Y = 14.5069 + 0.0187(X19) - 3.4387(X14) - 0.0657(X12)$	0.402
August 15, 1982	$Y = -0.6928 - 3.2833(X1) + 0.0381(X19) + 0.4561(X17) + 5.7701(X2) + 3.2719(X8)$	0.660
October 15, 1982	$Y = 12.2734 + 0.0373(X19) - 0.0179(X18) - 2.0321(Xg) - 0.0799(X13) - 30.6170(X23)$	0.379
May 30, 1983	$Y = -0.4496 + 2.2063(X1) + 0.0531(X19) - 0.0157(X16) - 0.7331(X5) + 0.2471(X4)$	0.766
September 15, 1983	$Y = 2.4329 + 0.0677(X15)$	0.428

[1] All models significant at $P<0.15$.

Table 5.--Mean sediment production (lb/ac) from 10.76 ft rainfall simulation plots for seasonal burning treatments and unburned controls by sampling date, silt loam soil initially at field capacity, in a longleaf pine/pinehill bluestem association near Alexandria, Louisiana

	Collection dates [1][2]			
	June 7, 1982		October 20, 1982	
Burning treatments	X	S_X	X	S_X
Unburned control	$119.25^{a(a)}$	50.98	$690.61^{a(a)}$	200.06
Winter annual	$82.98^{a(a)}$	25.88	$493.86^{a(a)}$	73.99
Spring annual	$56.83^{a(a)}$	17.71	$464.90^{a(a)}$	95.42
Winter biennial	$95.85^{a(a)}$	26.80	$677.16^{a(a)}$	183.60
Spring biennial	$59.71^{1(a)}$	19.99	$639.71^{a(a)}$	301.35

[1] Means followed by the same letter within each column are not significantly different (P<0.05) according to analysis of variance and Student-Newman-Keuls multiple range test.

[2] Means followed by the same letter in parentheses within each column are not significantly different (P<0.05) according to analysis of covariance, >0.08 in sand fraction as a covariate, and Student-Newman-Keuls multiple range test.

export levels within published criteria for soil loss and water quality (Lear and others 1985).

Biennial burning of the sandy loam unit for 22 years has maintained dominance by longleaf pine and fire-tolerant grasses and forbs. Prescribed burning in 1982 may not have produced enough heat to alter soil structure. Burning removed soil surface cover, exposing plots to raindrop impact and the potential for surface sealing, increased runoff and concomitant sediment production.

Short-term effects of treatment-year burning were increases in sediment production from winter- and spring-burned plots. This was mainly attributed to the removal of protective surface soil cover and exposure of mineral soil to raindrop impact. Winter-burned plots had exposed mineral soil for a longer period than other treatments prior to the inception of spring growth. The potential for increased sediment transport from intensive storm events existed during this period. Significant sediment was moved from winter-burned rainfall simulation plots as the result of an interaction between we surface soil conditions and dislodgement by raindrops. This circumstance provided a sedimen source and runoff as a conveyance mechanism. Sediment production for both treatments was similar to unburned controls at the end of the growing season. Vegetative cover for both winte and spring treatments was restored quickly (within ten months) and compensated for mulch removed by burning. Knight and others (1983) have found a similar compensatory relationship for sediment yield under a burning/herbicide treatment regime in Texas.

The summer treatment occurred under atypically wet conditions, exposing less mineral soil than either winter or spring treatments. Sediment production from the summer-burned plots was similar to unburned controls. By the end of the treatment-year growing season, no treated plots were producing significantly more sediment than unburned plots.

It was assumed that rainfall simulation sampling of the sandy loam unit in 1983 measured the effects of longterm burning. Results provided no evidence for perpetual effects of burning on sediment production for treated plots when compared to unburned controls.

Table 6.--Mean bare ground (%) by burning treatment and sample date, silt loam site in a longleaf pine/pinehill bluestem association near Alexandria, Louisiana

	Collection dates [1]			
	June 7, 1982		Oct 20, 1982	
Burning treatments	X	S_X	X	S_X
Unburned control	2.83^{a}	2.46	0.17^{a}	0.17
Winter annual	2.50^{a}	1.54	1.33^{a}	0.61
Spring annual	2.83^{a}	1.64	1.00^{a}	0.36
Winter biennial	1.50^{a}	0.81	1.33^{a}	0.49
Spring biennial	7.83^{a}	2.65	2.33^{a}	0.76

[1] Means followed by the same letter within each column are not significantly different (P<0.05) according to analysis of variance and Student-Newman-Keuls multiple range test.

Table 7.--Sediment production regression model by sampling date all treatments combined, soil initially at field capacity. Silt loam site in a longleaf pine/pinehill bluestem association near Alexandria, Louisiana

Sampling date	Regression equation[1]	Coefficient of determination (R^2)
June 7, 1982	$Y = 4.4373 + 15.3669(X22) - 0.5489(X11)$	0.235
October 20, 1982	$Y = 2.5005 + 0.0283(X15) + 3.7874(X8) + 0.4125(X11)$	0.397

[1] All models significant at $P<0.15$.

Prescribed burning in the longleaf pine/bluestem association on a silt loam soil selectively removed broadleaf woody species and susceptible conifers independent of burning cycle and season. All plots contained nearly complete surface cover available for intercepting raindrop energy. Sediment production was limited to organic matter and small amounts of mineral soil floated from mulch layers beneath undisturbed control plots. Repeated burning did not significantly increase sediment production when compared with control plots. The potential for soil loss may be great immediately after burning a highly erosive silt loam site. However, assuming a rapid recovery of the vegetation and typically flat terrain, stabilization of the site should occur quickly without perpetual soil losses.

Variables influencing sediment production in a longleaf pine/bluestem association include bare ground exposed, grass cover and standing crop, litter cover, surface sand, and surface silt during the treatment year; antecedent soil moisture, bulk density, surface silt, and surface clay during the 1983 post-treatment year.

Severe wildfires may drastically affect vegetation and soil, resulting in alteration of hydrologic parameters and processes. Prescribed burning under the environmental conditions existing in the southern forest is not likely to have appreciable effects on sediment production. Fire temperatures are not extreme and consumption of forest floor biomass is relatively small. Humidity, temperature, and length of growing season interact to promote rapid recovery of surface cover. Sediment yields are restricted to relatively short periods when bare soil is exposed. These losses could be managed by spring burning, as summer burning eliminates longleaf pine seedlings (Grelen 1975). Application of prescribed burning on a biennial cycle provides adequate time for plant and litter cover to return to preburn levels. Although burning has greatly shifted community composition, perpetual effects of 22 years of biennial burning on sediment production from a sandy loam soil and 10 years of annual and biennial burning on sediment yield from a silt loam soil are not evident.

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Social Aspects of Southern Forest Grazing

John H. Peterson, Jr.

Major factors affecting potential expansion of forested grazing were identified in a pilot study using historical research, demographic trends and in-depth interviews with cattle men and Forest Service personnel.

INTRODUCTION

The Southern Evaluation Project approved by the Chief of the U.S. Forest Service in 1978 is one of the first efforts to scientifically evaluate multiple use of management of southern forest lands for both food and fiber production. Forested grazing of cattle in the southeast United States is viewed by many southern foresters and animal scientists as an undesirable survival of earlier practices associated with southern frontier subsistence agriculture. Forested grazing is often approached as a problem which will be eliminated as older farmers retire and are replaced by younger, better educated farmers who will convert land usage to more intensive mono-crop production. Cattle would be concentrated on improved pastures while improved timber management would convert forested lands to tree crops.

The trend to more intensive mono-crop production of cattle and timber in the South is parallel to developments taking place in many areas of the world. Economic benefits and management practices have been examined primarily from the perspective of a single scientific discipline such as forestry or animal science. There has been little scientific assessment of more traditional forest grazing practices, and little effort to develop scientific approaches to management of forested grazing in the Southeast. Indeed, southern forested grazing is a phenomenon which, until recently, has received little attention from social historians, social scientists, or resource scientists. This is ironic since in recent years integrated production systems of forests and crops or improved grazing are attracting increased attention in many parts of the world.

The Southern Evaluation Project

Efforts to better understand scientifically the possibilities of forested grazing are relatively new to the South, and have been undertaken primarily by the U.S. Forest Service. Although foresters and animal scientists tend to view forested grazing as an undesirable tradition practice, the U.S. Census of Agriculture indicated that in 1978 50% of farm forests in Mississippi were grazed, Forest grazing is permitted by many of the major timber companies holding larger tracts of land. But this is viewed as a traditional practice which is continued to maintain good relations with the surrounding population. In simpler terms, it is cheaper for the timber companies to try to regulate the grazing to prevent damage to the timber than to try to control losses from woods arson which often accompanies attempts to eliminate grazing. Although interest in improved management of forest grazing has been expressed in recent years by both timber companies and regional foresters, the first major study of forest grazing in the Southeast was undertaken by the U.S. Forest Service.

The U.S. Forest Service has long recognized that population increases result in greater competition for the use of land and that this requires that the nation's forest and rangeland needs to respond to multiple needs including livestock, timber and wildlife. The USDA Forest Service (1972) made a nationwide study of grazing potential with predictions concerning livestock grazing of forested lands and interactions with other resources. The Resources Planning Act of 1974, the Resources Conservation Act of 1977, the National Forest Management Act of 1976, as well as the earlier Multiple Use Sustained Yield Act of 1960 provided the legislative basis for multiple use management of forest and rangelands.

To carry out the intent of these acts and to evaluate multiple use interactions in the South, the Southern Evaluation Project was conceived, and the Chief of the Forest Services approved the project in September 1978. The objectives were:

1. evaluate impacts of timber, wildlife and range management alternatives from a biological, physical, economic, and social standpoint;

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2. provide appropriate technology transfer;
3. demonstrate selected management strategies on an operational scale.

The Social Assessment Study

The responsibility for drafting a social assessment framework was given to Mississippi State University through a cooperative research contract in the summer of 1981. Because of the broad nature of the project, an interdisciplinary team was established consisting of an archaeologist, an historian, a cultural geographer (demography), and a social anthropologist. The initial assignment was to carry out a preliminary social reconnaissance of the Mississippi test area and from this draw up a research plan for the collection of baseline data on all sites which would also permit the measurement of social changes resulting from the project (Snow and Peterson 1981).

The archaeological component of the research was deemed required by applicable federal law and consisted of a reconnaissance of the study area by a Mississippi State University archaeologist cooperating with the U.S. Forest Service archaeologist for the State of Mississippi (Marshall 1981).

The historical element in the study was included because forested grazing is a well-established traditional practice and it is probable that perspectives on traditional forest grazing will affect the perceptions and responses to modern forms of extensive and intensive forest grazing. Further, the six study areas represent a significant diversity in recent settlement or population history and also a diversity in recent grazing history. For these reasons it seemed essential for intersite comparisons that baseline data include a brief historical element (Atkinson and Peterson 1981).

The historian, geographer and anthropologist conducted preliminary interviews with local individuals knowledgeable about grazing practices in the study area. The historian supplemented historical documentation with oral history interviews with persons with long grazing experience, while the geographer and anthropologist supplemented interviews with an analysis of available statistical data on the study area (Snow 1982).

The primary purpose of the preliminary research was only to ascertain availability of data sources for further study. Therefore, any conclusions must be very tentative. Because of cutback in funds, the social assessment phase never went beyond the pilot study and research design phase (Peterson 1982). Thus the research I report represents a preliminary view of only the Mississippi test site which was never intended to be a complete research project. With this in mind, we will summarize certain aspects of southern forested grazing as they appear in the Mississippi study area.

HISTORICAL ORIGINS OF SOUTHERN FOREST GRAZING

Before examining the current status of forested grazing in the DeSoto National Forest, it is useful to renew the historical origins of southern forest grazing.

Early Cattle Herding in the Southeast

Cattle were initially introduced into the Southeast by the Spanish, and formed the basis of the wild herds encountered later on the Atlantic coastal plain by the English colonists (Towne and Wentworth 1955). Not only was the established cattle stock on the mainland significantly derived from the Iberian longhorns, but cattle-keeping practices such as open range grazing, roundups, branding and marking, horsemanship, and overland drives to market were also derived from those practices on the Iberian peninsula. Latin American cattle ranching was transferred directly from Iberia (Bishko 1952) and Anglo-American ranching practices indirectly through the migration of British West Indies colonists to the mainland, the English herding industry having displaced the earlier Spanish cattle industry on those Atlantic Islands (Gray 1933). While relatively unresearched, it would also appear that the open ranging of cattle on unimproved common lands in the southeast also has a strong antecedent in the grazing practices of the Welch and Scotch-Irish who formed the bulk of the settlers in the U.S. southeast.

These grazing practices predominated in the early settlement period in the interior backwoods of the new southern colonies with back country settlements serving as suppliers of the coastal settlements (Vance 1935). The well-known Revolutionary battlefield, the Cowpens in the Carolina Piedmont, is the most conspicuous example of this widely-established practice. A description of backwoods cattle practices as observed in the North Carolina Piedmont in 1783-84 show strong continuity into this century:

> With the most careless handling domestic cattle have increased with the greatest rapidity. It is nothing uncommon for one man to own 100 or more head of horned cattle; some count their herds by the thousands, all running loose in the swamps. By penning up the calves, and throwing out a little corn every day to the dams, the milch cows have been accustomed to come up to the dwelling-house from time to time to be milked. For each farm, the black cattle, sheep, and hogs are distinguished by special earmarks; horses are branded. Each planter's own peculiar mark is registered by law, and is thus legitimate proof of ownership, and extinguishment or falsification of these marks is treated as felony. There is little beef salted for export; what is salted is said not to keep

> well, and to grow hard and lank. In general, the beef is of no especial goodness in any of the provinces south of Pennsylvania and Maryland; the cattle themselves small and thin. . . . large herds are driven up from the farther regions to Pennsylvania, and there fed for the Philadelphia market. Out of the woods and thin as they are, one head with another is sold to the cattle-handlers at 3 to 6 Spanish dollars; and to the owner, has been at so little trouble and expense, this is almost clear gain (Stephenson 1954).

The extensive cattle herding practiced in the early years has been described as the time when a true cattle kingdom existed in the southeast. In southeastern Mississippi, Israel (1970) has shown that a decline in the cattle industry began shortly after 1840, and by 1860 the end of the early cattle kingdom was near. By the latter date, the human population had increased to the point where much former public domain land had been sold to settlers, thereby restricting its free use by the herders. In order to cultivate crops settlers burned and cut the extensive cane breaks which provided winter forage, and many types of non-winter forage vegetation had been destroyed due to many years of overgrazing and/or excessive burning (Moore 1958). Contributing to the decline in the piney woods areas was the increase during the 1840s and 1850s of subsistence pursuits based on lumber, tar, and turpentine, uses of the land which further reduced the open range (Hickman 1962).

While the increased agricultural population and beginnings of forest industry did restrict the expanse of open range, this was a gradual process. In most areas local tracts of open range continued to be available until well after the Civil War, even in prime agricultural areas. Young's (1961) study of land use following Indian removal indicates that even in DeSoto County in northeast Mississippi, where 90 percent of the soil was "loess" or "brown loam," approximately one-quarter of the land was still held by absentee owners as late as 1860. Both the landowner's own forested acreage and these "unoccupied" tracts continued to be used for grazing. In areas not well suited for agricultural use, such as south Mississippi, the percentage of lands not owned by local owners was much higher and the continued use of forested grazing was more extensive.

The Clear-Cutting Era and Its Repercussions

In many areas of the southeast the early lumber industry depended solely on natural streams for the transportation of logs to sawmills. In the late 19th century, however, a significant increase in railroad construction began, providing a more efficient and economical method of transportation. At the same time, the demand for southern wood was increasing because of depletion of the northern forests. These circumstances resulted in a tremendous boom in sawmill construction along the railroads as the centuries-old virgin timber began to be extensively cut. By 1900 numerous large lumber companies were in operation wherever virgin timber still existed, which was primarily in areas with poor agricultural soils or where the terrain was unsuitable for agriculture. By the early 1930s the virgin forests of the South were practically gone. The large lumber companies closed down operations as an area was denuded, leaving behind them vast wastelands of stumps. At the same time wildfires ravaged the cut-over lands, destroying the new seedlings which otherwise would have reforested the land naturally. These annual fires, however, removed obstacles to grass growth, resulting in millions of acres of open range conducive for grazing. Knowing the benefits of fire to grazing, many of the fires were intentionally set by livestock farmers. Grazing at this time was still poorly managed and few government restraints were attempted. In addition to cattle, hogs and sheep were also grazed, animals which were quite detrimental to young seedlings (Grelen 1978).

In 1891 Congress gave the President power to create forest reserves (later becoming National Forests), a measure which ultimately led to reforestation of much of the cut-over land not suitable for agriculture. Attempts to reforest the areas were initially hindered by grazing and the accompanying, deliberately-set annual fires, but by 1927 most southern states had outlawed forest arson and had created forestry agencies to enforce fire prevention. Opposition to laws restricting the open range resulted in continued woods arson by persons opposed to interference with the traditional open range (Grelen 1978; Lee 1980).

After World War II, most of the cut-over lands that had formerly belong to the exploitive timber companies had been purchased by large, stable timber companies which strove to regenerate the pine forests through planting and direct seeding. Regeneration and the desire to protect the private and governmental investments brought about an increase in the number of fences and stricter enforcement of stock laws. Better fire protection efforts, as well as prescribed burning in young plantations further promoted the regeneration of the forests. As a result of forest regeneration, the grass forage underneath the pines decreased, forcing many individuals to reduce their livestock herds or even sell out. In the early 1960s, intensified efforts were made in the National Forests to promote better management of grazing in order to protect the total environment, including vegetation, wildlife, soils, and water (Grelen 1978).

Southern Forest Grazing Today

In comparing the early herding practices to modern times, the termination of open range because of enforced stock laws is the most significant change. No longer can vast numbers of cattle, sheep, and hogs roam unrestrained in the forests as they did until well into the 20th century. Another significant change, caused by environmental modifications and better cattle-keeping practices, concerns the cessation of winter grazing without supplemental feeding. Unlike today, many cattle were once allowed to graze year-round without supplemental feeding because of the presence of evergreen cane, a vegetation type that once existed in abundance, but is scarce today. When abundant, the cane provided winter forage for cattle when the other types of vegetation died or became dormant. Today cattle are usually taken out of the forests during the winter and fed, but some farmers prefer to leave them in the forest during the winter while also providing them with hay and other feed. In regard to sheep, the stock laws seem to be the primary reason why once extensive holdings of sheep by farmers have not generally been reduced to small holdings kept around the farmhouse for home use. With the disappearance of the open range, farmers could no longer graze large holdings on the reduced territory available to them on the public lands.

CONTEMPORARY FOREST GRAZING IN THE DESOTO NATIONAL FOREST

From these general observations on southern forest grazing, we now direct our attention to forest grazing in the DeSoto National Forest in 1981. First, however, it is necessary to briefly examine the specific study area.

The Mississippi Study Area

The Mississippi study area lies in the southern portion of DeSoto National Forest, 22 miles north of Gulfport on the Mississippi Coast and 50 miles south of Hattiesburg, the nearest large town to the north. The DeSoto National Forest was established in 1936 and today comprises some 500,000 acres. The sandy soils of this portion of the Gulf Coastal Plain are generally poorly suited for agriculture. Prior to the 20th century, economic pursuits in the area were primarily cattle farming, sheep raising, lumbering, and naval stores. Even today only about 25% of the land area surrounding the study area is in farms and a much smaller proportion is in crop land. DeSoto National Forest is currently one of two in Mississippi where grazing or the potential for grazing is significant for the local economy.

History of Grazing in the Study Area

Historical documentation on traditional grazing in this region is very poor. Forested grazing is mentioned in the historical record primarily in the context of development of railroads, the port at Gulfport, the timber industry, and later highways. Usually such information is on the negative impacts of traditional practices on opportunities for development. Historical studies of the timber industry (Hickman 1962) and local histories (Lang 1936) mention forested grazing, but usually as a side issue.

The clearest picture of traditional grazing comes from oral history interviews. One 60-year-old man, living adjacent to the study area, introduced us to his father who remembered the earlier days of open range grazing. He recalled times when you could drive cattle from Gulfport to Hattiesburg without being bothered by roads or fences. This was a time when you could stand on your porch and see the land in all directions not being blocked in by the trees. Cattle were taken to market by driving them to the coast, but sheep were mostly driven to a place in Harrison County on the Biloxi River called Woolmarket.

Increased control of fire and reseeding of the land was carried out following acquisition by the government, and state and federal laws and regulations eventually resulted in the demise of the open range and a significant reduction in livestock numbers. The landowners today holding grazing permits for National Forest lands do not seem to resent the coming of highways and fences, national commercial forests. But older newspaper editorials suggest that this acceptance of the modern landscape was once strongly opposed. While most local residents do not recall the coming of fences and the initial permit system, they do recall the stock reduction carried out more recently through limitation of permits and numbers of allowable cattle per permittee. Prior to 1963, livestock grazing in the forest was largely uncontrolled. Excessive numbers of cattle and sheep were allowed to graze, resulting in substantial damage to all resources. Presently, grazing areas and numbers of cattle permitted are tightly controlled by the Forest Service, but problems stemming from various factors are limiting the use of the forest for grazing.

Grazing of sheep is no longer significant, but in the 1940s and 1950s some farmers were grazing sheep herds as large as 1,000 or more in the National Forest. Those farmers who have sheep today own only a few, and these are kept around the farm for food rather than for wool production. Although most individuals stated that they ceased raising sheep because dogs were killing so many of them, a more realistic and underlying reason appears to be that the demise of the open range and the grazing fees made it impractical, if not impossible, to raise sheep in large numbers. At present there seems to be no thought given by any of the permittees to attempt large-scale sheep raising again.

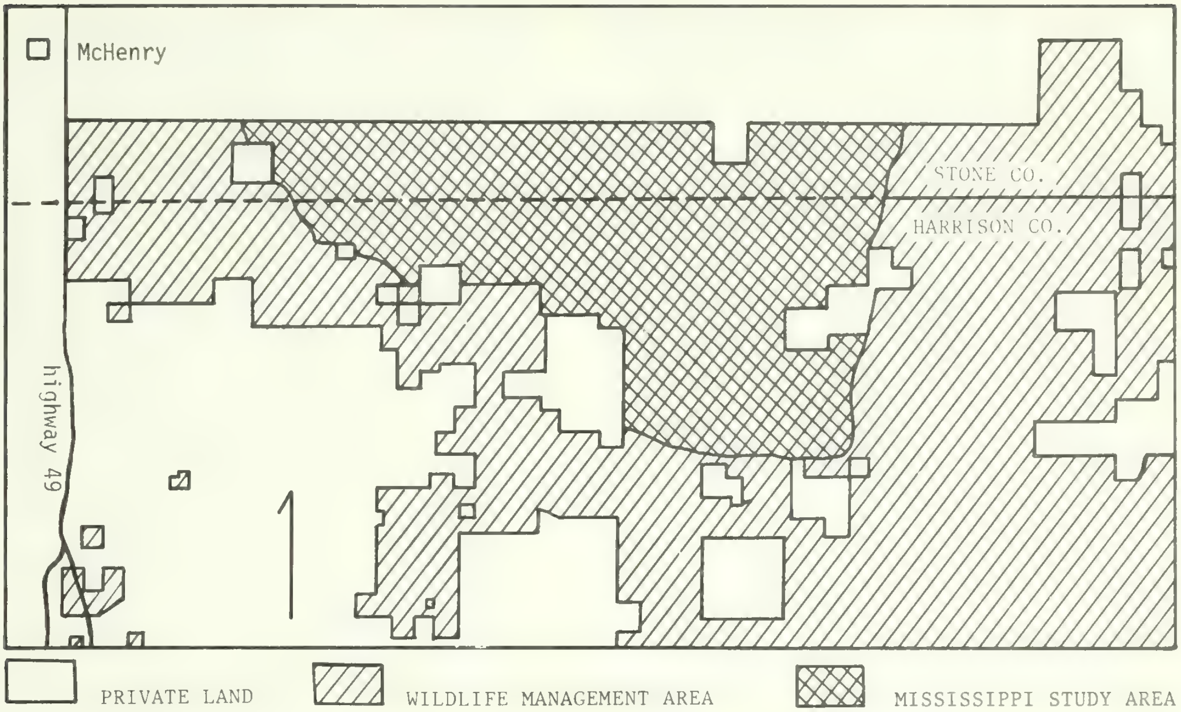

Figure 1.--Mississippi study area DeSoto National Forest.

Types of Grazing Operations

The DeSoto National Forest lands in south Mississippi do not constitute a solid block of land, as is more typical in the western United States. Nor do the residents having grazing permits for the National Forest lands resemble the ranchers grazing the western National Forests. DeSoto National Forest resembles a checkerboard with numerous small farmsteads scattered through the forests. The Biloxi Ranger District, in which the study area is located, had about 35 persons with grazing permits in 1981. Most of these permittees ran only about 30 head of cattle. Each permittee was required to pay $.62 a head per month, build and maintain fences (furnished by the Forest Service), and see that each of his cattle are ear-tagged by Forest Service personnel. Numbers of cattle a farmer can run on a certain area are controlled by the Forest Service in order to prevent damage to the total environment. Watering ponds in grazing areas without natural water are constructed by the Forest Service.

In August 1981, a field reconnaissance was conducted by Mississippi State University in the DeSoto National Forest for the purpose of gathering base line data for planning more in-depth future socio-economic studies of grazing potential in southern forests. Following is a summary of this data as obtained through interviews with nine permittees or former permittees residing on the north, south, and east sides of the study area. The nine interviewees appear to be a valid sample of the different classes of cattle grazer in the area. All but one of the present or past grazers are between 55 and 70 years of age, and have 50 or more years experience in cattle raising. The remaining permittee, who is 76 years of age, stopped cattle grazing about 10 years ago. Seven of the individuals are white and two are black.

Farmers tend to have somewhat of a proprietary attitude toward grazing rights in lands adjacent to their own holdings. Approximately seven farmsteads are located immediately adjacent to the study area (Figure 1). It is probably that these landowners would feel that they have first call to any more extensive grazing rights in the study area. This is partially a result of practical considerations on the part of the permitees as will be discussed below.

Among the individuals interviewed there were three types of cattle farmers. First, there were two full-time cattle farmers with 100 or more cattle which constitute their primary source of income. These farmers are very appreciative of the Forest Service grazing lands, for without them they would not be able to conduct large-scale cattle farming and would either have to rely on other sources of income or have a lower standard of living. In addition to the Forest Service land, they also graze on commercial timber company holdings. Both of these individuals are running cattle on some of the better areas for grazing in that permanent water-sources (creeks) are present. One of these individuals stated that the present Forest Service grazing program is the best ever and does not need to be changed. He also stated that he puts his cattle in the forest on April 1st and in six weeks they are "mud fat." These individuals seem to put the advantages of using the non-owned grazing lands above the problems and disadvantages that are faced by all the permittees. These individuals are the ones most likely to benefit from an expanded grazing program in the National Forests since they have the capital, the time, and are young enough to adapt to a more intensive operation.

In addition to the full-time cattle farmers, there are two types of part-time cattle farmers. These are similar in that neither of them derive their primary income from their cattle operations. One type of part-time cattle grazer is the older farmer who is semi-retired, but who keeps cattle as a source of supplemental income. In many cases these individuals previously managed more cattle, but no longer have the ability or interest to continue to do so. Similar to these semi-retired farmers in orientation toward their cattle is the younger individual who has a job in a nearby town, but who continues a part-time farming and cattle operation for supplemental income. These individuals have a family tradition of cattle raising. Unlike their fathers who depended upon it for a livelihood, their primary source of income is from jobs or businesses in nearby cities. One such individual, for example, owns several business establishments in Gulfport. A hired hand living on the old home place looks after his cows, but the owner comes out once or twice a week to check on things and just to be with his cows.

The part-time cattle operators, whether semi-retired or holding a non-farm job, have certain characteristics in common. They generally lack the ability to significantly increase their cattle-management effort either because of age or because of the demands of their primary occupation. As a result they tend to find the problems resulting from other human activities more acute. Further, in most cases, since their cattle operation is secondary in terms of income, they do not view their cattle as a major source of income. For many it is a second or even special purpose income. Cattle are sold when a down payment is needed on a new pickup truck, or other special cash needs arise. Thus cattle are partially income and partially like money in the bank. The personal desire to have cattle apart from any financial gain is also an important factor for these individuals. In most cases, these individuals could not invest either more time or capital in an expanded intensive cattle operation, even if people problems were reduced.

The proprietary attitude toward grazing rights in lands adjacent to private holdings was mentioned earlier. This partially reflects the fact that most holders of grazing permits are not interested in transporting cattle to a grazing area not near their farms.

The Cattlemen View People Problems

While all cattlemen recognize the same "people" problems, the larger owners feel these problems are manageable. Smaller operators seem to feel these problems more acutely. Four individuals interviewed once had medium cattle holdings. But finding the problems intolerable, they have discontinued grazing on non-owned land and reduced their holdings.

Invariably the primary reason given for not renewing their permits was the "people" problem, but other factors were usually given also. These individuals complained about the increasing numbers of people using the forest. Since cattle are presently being tagged, all individuals interviewed are concerned about liability if one of their cows should get out and be hit by a car. The difficulty here arises from the not-infrequent cases where people leave down gaps or cut fences, problems which the farmer cannot control. Other people-related problems include chasing of cattle on motorcycles (in some instances cows have been run to death), shooting cattle and sometimes butchering them on the spot, and stealing cattle. Some individuals blame the Forest Service for not doing enough to alleviate these problems by educating the public through such measures as putting up signs warning people that cattle are present and that gaps should not be left open. Some of the farmers were particularly aggravated by the Forest Service timber contractors leaving the fences unrepaired after cutting them to get into an area and also leaving fences down after letting trees fall on them. The timber contractors are required by the Forest Service to repair the fences. According to the cattle farmers, contractors do not always repair fences and, often, when they do so, it is done in such a sloppy manner that they fall apart again. These problems are of great concern to all permittees, but some persons interviewed stated that they would resume Forest Service grazing if the people problem could be solved.

Permittee Fees

Most holders of grazing permits did not object to permittee fees. There were some exceptions, but these seemed unrelated to the economics of the grazing operations since one of the strongest complaints came from one of the more wealthy permittees who was clearly not raising cattle for profit. On the other hand, one of the poorer permittees, a black man about 60 years of age, had no objection to the fees possibly because he grazes all year around and does not feed his cattle during the winter as do the others. As a result, however, his cattle get very poor and weak during the winter, according to one of the forest rangers.

Grazing in the Immediate Area

One of the drawbacks to more widespread

grazing in the forest is that most cattle farmers are generally not inclined toward transporting cattle to a grazing area not near their farms. No interviews were conducted with non-grazing cattle farmers living long distances from the forest, so attitudes toward long-distance transport among those farmers were not ascertained. All the present permittees live near their grazing areas on the fringe of the forest. Most farmers apparently prefer to have their cattle nearby so they can keep an eye on them. The people problem discussed above is a significant factor in this attitude. But some of the farmers do not have the equipment to transport cattle, even if they wanted to, and are not financially able to purchase necessary trucks. One of the large cattle raisers indicated he would be interested in transporting cattle to an area removed from his residence if grazing permits were available. The other large operator said he would consider it. One ex-grazer said he would not only resume grazing, but would also be willing to transport if the people problem could be solved. In view of these favorable attitudes toward transporting cattle to other grazing locations by larger cattle farmers, there may be a potential interest in transport grazing among similar cattle farmers living outside the immediate forest area.

A factor in transporting voiced by the permittees concerns the habit that cattle have of wanting to return to the area where they were raised. Thus, those cows transported would have to be young ones, for old cows would constantly be trying to get out and return to their old territory. In view of the cut fences and open gates problem discussed above, this is obviously a real problem. It can readily be seen that all these problems would be most acute for those individuals whose cattle operation was only a part-time activity.

Other Forest Users

The perspective of holders of grazing permits on "human problems" has been discussed above. Naturally, the perspectives of these other forest users can be expected to differ greatly from that of cattlemen. Although time did not permit interviewing a representative sample of these other forest users, it is clear that their perspectives may differ quite markedly from that of the cattlemen. The Mississippi Study Area is a popular recreational area with both a horseback trail and a hiking trail traversing the area. In addition to individual recreationalists and organized local groups such as Boy Scouts, groups from as far away as the Sierra Club from New Orleans and the R.O.T.C. units from the University of Southern Mississippi make use of the area. Local cattlemen feel that the problem of closing gates is particularly attributable to the recreational use of the area by non-local residents who are unaware of the grazing program and potentially unsympathetic to the concept of grazing cattle in "natural" forested areas. Tire marks from trail bikes found in our visit to the study area clearly demonstrate this emerging new recreational use, which is probably at odds with both cattle grazing and more traditional forms of outdoor recreation.

Hunting is another form of recreation with potential conflicts for cattlemen. The potential conflict between cattle and deer for food is one of the more important biological aspects of the Southern Evaluation Program. But even if tests prove that conflict between cattle and wildlife for food is minimal, there remains the conflict between hunters and cattlemen. When cattlemen remove their cattle from the woods during the winter this conflict is somewhat minimized. But hunters tend to return to the same hunting camp year after year and perceive informal ownership of camp locations. As with other recreationists, an increasing number of hunters are apparently coming from the nearby urban areas of coastal Mississippi and represent an increasing human pressure on the land resources of the National Forests.

Not enough is known about these other forest users at the present to anticipate how their presence may affect forested grazing in the DeSoto National Forest. Certainly this is an important factor in determining the success of the grazing programs and must be taken into account in planning research and management plans.

Area Demographic Trends

The conflicts between recreational users and forested grazing make the study of demographic trends in the two county area surrounding the Mississippi study area of special importance (Snow and Peterson 1982). Only the major points of this study will be reviewed here. The Mississippi Gulf Coast was relatively underpopulated before 1920 (See Figure 2).

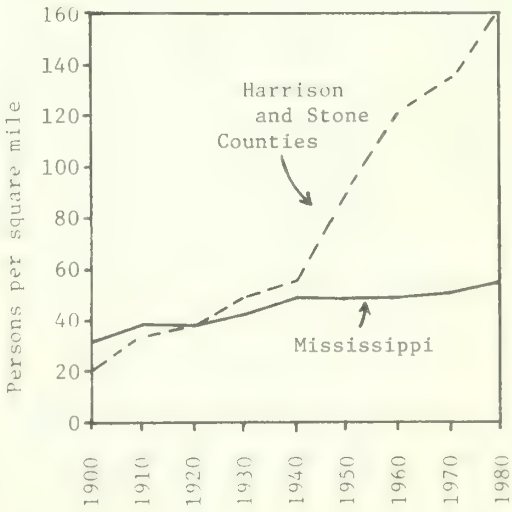

Figure 2.--Population density (Persons per square mile), 1850 - 1980).

Since the end of World War Two, Harrison and Stone Counties have experienced the rapid population growth characteristic of the entire Gulf Coast.

The majority of this growth through 1970 was in the urban population of the two county area as shown in Figure 3.

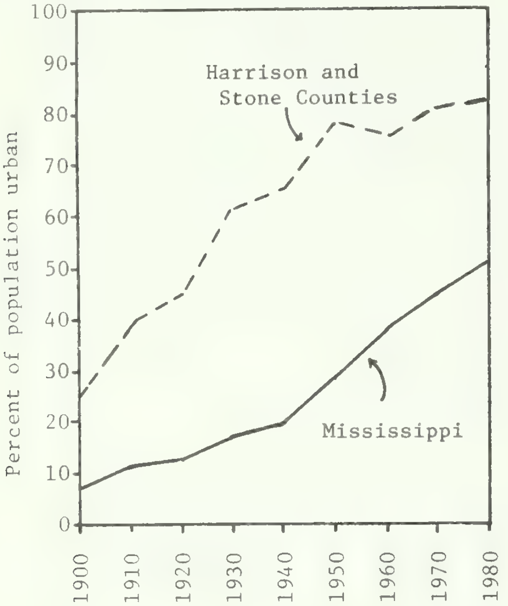

Figure 3.--Percentage of population urban, 1950 - 1980.

Between 1970 and 1980, the major population growth occurred in areas outside the major incorporated places. This suburbanization has been widely described as a retreat from urban areas into the surrounding countryside. As Table 1 indicates, between 1970 and 1980 the two major towns in the area, Biloxi and Gulfport remained almost static in population, while major growth occurred in the smaller towns and the unincorporated areas of coastal Harrison County. Stone County, inland from Harrison County and on the north or inland side of the Mississippi Study area, experienced a growth about the same percent of change as Harrison County. With only one small town, the growth in Stone County, like Harrison County, concentrated in the unincorporated areas along major transportation routes to the coast. Thus not only was the total population growing rapidly, but the population was shifting from the incorporated areas into the countryside closer to forested lands.

A further indication of this change is the rapidly decline of farm woodland as a percentage of the total land area in the two counties, as shown in Figure 4. In both Harrison and Stone County, individual farm woodlands have dropped from 13 to 16 percent of the total land area in the 1950s to 3 to 6 percent in the 1970s.

Table 1.--Population of incorporated places in Harrison and Stone counties 1970-1980

	1970	1980	Percent change 1970-198
Harrison County			
Biloxi	48,486	49,311	1.7
Gulfport	40,791	39,676	-2.7
Long Beach	6,170	7,967	29.1
Pass Christian	2,979	5,014	68.3
Remainder of county	36,156	55,697	54.0
County total	134,582	157,665	17.2
Stone County			
Wiggins	2,995	3,205	7.0
Remainder of county	5,106	6,511	27.5
County total	8,101	9,716	19.9
Area Total	142,683	167,381	17.3

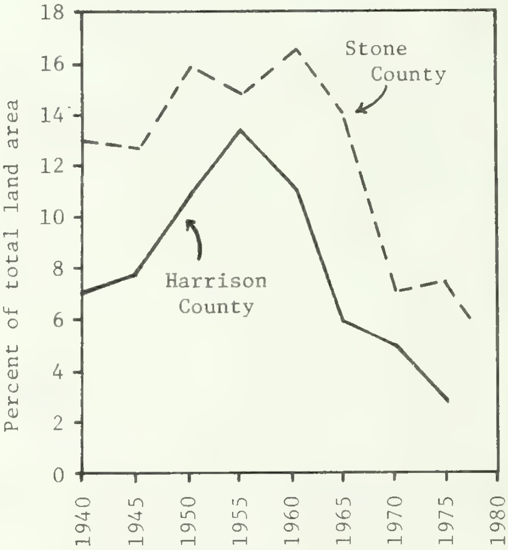

Figure 4.--Farm woodland as a percentage of total land area.

Implications of Demographic Trends

There are obvious and important implications in these demographic trends for the future of forested grazing in the southern half of the DeSoto National Forest in which the Mississippi study area is located. First, the level of recreational use can be expected to continue to dramatically increase. This use will increasingly be by non-local, urban residents who have little appreciation for forested grazing, and who lack knowledge of even the fundamentals of rural courtesy such as closing gates. Further the demand for both recreation and housing outside existing urban areas will result in high demand for forested land outside the National Forest. The sharp decline in farm forest land in the two county area already demonstrates this pressure. Except where land is made available for forested grazing in the National Forests or in commercial forests, no significant continuation of forested grazing is possible in the vicinity of the Mississippi study area. Both commercial forests and the National Forests will experience increasing demand for recreational purposes which conflict with forested grazing. Thus while the Mississippi study area is ideal ecologically for research on forested grazing, the demographic trends in the surrounding area indicate that such an experiment is probably doomed to failure in the longer run because of the pressure for human use. These conclusions about demographic trends apply only to the Mississippi study area.

The long-range possibilities of forested grazing in the Mississippi study area and other forested areas near population centers may be limited more by demographic considerations than by biological factors. Demographic trends and related non-forest, non-cattle, use of the forests would seem to be very important in considering the long-range possibilities of forested grazing in the Southern National Forests. In this regard, it is most unfortunate the limitations of funds prevented the expansion of this analysis to other study areas which could be expected to have quite different demographic characteristics.

IMPLICATIONS FOR FURTHER RESEARCH

There are some important implications to be noted from this preliminary view of current grazing operations. Since expanded grazing demands an increase in management time, many of the current holders of permits will be unable or unwilling to respond to a new opportunity. But since individuals currently holding grazing rights near their homesteads view this as a long-standing right, they may tend to resent bringing in an outsider to graze lands now or formerly being used by them. The study team was informed of a case in an adjacent state where an outsider was given a grazing permit, but significant difficulties with neighboring landowners led to his ceasing operations. Based on current information, one could anticipate that the most successful response to an experimental intensified grazing program would come from the current larger cattle operators in forest areas where grazing is now permitted. Smaller grazers would be less likely to respond to the opportunities and more likely to resent the bringing in of an outside operator. In forest areas where grazing has not been allowed in recent years, the selection of a non-resident for the grazing experiment would probably meet less opposition. Here since the criteria of local residence would not be a factor, the conditions for finding the best person to implement a cattle management program would be best. But while bringing in an outsider to a non-grazing area would best meet the cattle management objective, the possibilities that the experiment would be observed and perhaps duplicated by other grazers in the immediate area would be reduced.

The implementation of a successful intensified grazing program would seem most likely where grazing is currently permitted and where pressure from other human users is minimal. Where other human activity is high and where grazing has not been allowed under permit in recent years, a grazing program could be expected to have the maximum amount of "human problems."

Finally, the attitudes on the part of the U.S. Forest Service personnel may be the most important factor in the implementation of the grazing experiment. Cattlemen believe that many of the problems they face in forested grazing are under the control of Forest Service personnel. Without the support and understanding of Forest Service personnel, successful grazing programs would be difficult. Forest Service personnel in areas currently being grazed may be expected to have more experience with forested grazing than in areas where grazing has not been permitted in recent times. Thus without a major educational program for Forest Service personnel, an intensified grazing program may be easier to implement in areas already experiencing grazing.

PREDICTION FOR SUCCESSFUL GRAZING PROGRAMS

Given the above factors and assuming that no major unknown factor is found operative in the other research sites, it may be predicted that the more successful implementation of experimental programs in southern forested grazing will involve a site which has the following characteristics:

1. An ongoing grazing program recognized by other forest users and understood by Forest Service personnel.
2. Recruitment of permittees for the project from among local current grazers utilizing primarily successful larger grazers capable and wishing to expand operations.
3. An area in which competition from non-forestry, non-grazing users is minimal.

Where these factors are not present, the successful implementation of an experimental forest grazing project will seem to depend heavily on the education of both Forest Service personnel and other forest users as to the importance of the grazing program.

SIGNIFICANCE OF THIS RESEARCH

Although the social research component of the Southern Evaluation Project was minimal, it afforded the first effort to examine the social factors surrounding one of the least understood of traditional southern agricultural practices. A better multidisciplinary understanding of all aspects of forest grazing could have important consequences not only for combined food and fiber production from southern forests, but also could contribute scientific findings of value to other areas of the world. Certainly, the long persistence of southern forest forested grazing and the wide use of the practice today on private woodlands suggest that there are lessons to be learned which, if scientifically applied, could result in significantly higher production from southern forested lands.

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Aggregate Economic Impact of Implementing Forest Grazing of Beef Cattle in the Southern United States

G. K. Lundgren, J. R. Conner and H. A. Pearson

Abstract.--Projected increases in the demand for grazable forage for beef cattle could potentially be met by utilizing Southern U.S. forests in conjunction with pulp-sawtimber rotations. Aggregate impact estimates of implementing beef cattle production in southern forests are obtained using TECHSIM, an economic simulation model of the U.S. agricultural economy. Results indicated that total welfare would be increased by implementation while producers of beef, pork and sheep could expect real decreases in the net returns for their products.

INTRODUCTION

It has been projected that the demand for animal unit months[1] (AUM's) of forage from grazing lands in the U.S. will increase 50% by the year 2000 (Forest-Range Task Force 1972). Thus, there arises a need to search for an alternative source of feed for livestock use. There are several strategies which would produce the projected demand for AUM's. One such strategy lies in extensive use of the forest-range environment in the Southern United States.

An estimated 1.2 billion acres, or 63% of the total land area in the 48 conterminous United States, is in forest-range environment. Sixty-nine percent of this, or 835 million acres, was grazed by livestock in 1970. Nearly 100 million acres of pine and oak-pine forest land in the southeast are potentially available for livestock production with almost a quarter of a billion acres available when pasture, cropland and hayland are added to the livestock forage resource (Shiflet, 1980).

Lundgren, et al., (1983) conducted a feasibility study of grazing cattle on four timber management regimes in the South. The timber management alternatives included a 30-year rotation without thinning, a 30-year rotation with thinning to 70 square feet of basal area per acre in year 15, a 40-year rotation with thinnings in years 15 and 27, and a 60-year rotation with thinnings in years 15, 25, 35, and 48. A moderately stocked, year-long grazing strategy was practiced on each timber management alternative. Positive economies were indicated for the alternatives, the highest being the 40-year rotation with thinnings.

Returns for grazing cattle on forested lands may be further increased by the implementation of a rotational grazing management system. It has been hypothesized that systems such as the Merrill four-pasture system and the Savory grazing method, or short-duration grazing, may result in stocking rate increases of 25 to 100 percent (Merrill, 1954; Savory and Parsons, 1980). In order to evaluate the application of grazing systems in forest grazing, an analysis of a year-long continuous and four rotational grazing systems were conducted (Lundgren et al., 1984). Each grazing management system was evaluated using a 40-year timber rotation with thinnings in years 15 and 27. Three levels of stocking were analyzed for each system. Results showed that if the short duration system would allow at least a 75% increase in herd size over the continuously grazed system, the opeator would be justified in choosing it. If not, the four-pasture, one herd system should be considered because it was estimated to produce the next highest rate of return at all levels of stocking.

These studies indicate that individual firms currently owning forest land in the South could expect positive rates of return on investments in

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[1] An animal unit month is the amount of forage required to support one mature 1,000 lb. cow, or the equivalent, for one month based on an average daily forage consumption of 26 lbs. of dry matter per day.

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beef cattle production enterprises on their forest lands used in long-term rotations with periodic thinning. However, these analyses only considered firm level costs and prices.

The objectives of this study were to examine the aggregate economic effect of beef cattle grazing in conjunction with a 40-year pulp-sawtimber rotation assuming three levels of implementation in the southern U.S., 50, 75, and 100 percent of total southern forest lands used for cattle grazing. The impacts were estimated for the target year 1990.

METHODS

The aggregate impact estimates used herein were developed by using TECHSIM, a simulation model of the U.S. agricultural economy (Collins, 1980; and Collins and Taylor, 1983). The impact of implementing beef cattle grazing of southern forest lands was introduced into the model as a small reduction in the average cost of production of fed and non-fed beef cattle in the U.S. The source of the lower costs was the reduction in land costs associated with that portion of the total U.S. beef cattle herd grazing southern forest lands under the alternative implementation assumptions. The implementation assumptions--50, 75, and 100--resulted in respectively larger reductions in average cost of production. It should be noted, however, that a 100 percent implementation would amount to about 3.5 percent o the U.S. beef cow herd receiving an approximate 10 percent reduction in the cost of production. Thus, the impact on the average cost of productio for the total U.S. beef cow herd is only about a .35 percent decrease.

RESULTS AND DISCUSSION

Total welfare, as a result of a 50, 75, or 100 percent implementation of forest grazing in the U.S., will increase by the year 1990. Howeve total welfare, reflecting the combined benefits accruing to consumers and producers in the U.S., is less than the final consumers' surplus (the benefits accruing to all consumers in the U.S.) because of the negative impact on the producers' and wholesalers' surplus (the benefits accruing to all production and wholesale firms in the U.S.) (Table 1.)

The reason for the loss in producers' and wholesalers' surplus is readily apparent when one examines the vertical effects (effect on different phases of the beef industry) and horizontal effects (effect on alternative livestock enterprises) of implementation of forest grazing in the U.S. At each level of implementation, fed

Table 1.--Estimated aggregate changes in consumers' surplus, total welfare and beef related industries resulting from forest grazing of cattle for target year 1990

	Units	50% Implementation	75% Implementation	100% Implementation
Total livestock final				
Consumer surplus	Mil $	2758.88	4150.57	5550.93
Total welfare	Mil $	2398.60	3579.46	4770.90
Vertical effects				
Cattle				
Fed beef net returns	$/head	-13.86	-20.74	-27.57
Non-fed beef net returns	$/head	-10.54	-15.75	-20.92
Calves placed on feed	Mil head	.72	1.09	1.47
Farm price	$/cwt	-2.89	-4.32	-5.74
Retail price	$/cwt	-9.61	-14.38	-19.12
Horizontal effects				
Sheep				
Net returns	$/head	-.69	-1.04	-1.38
Supply	Mil lbs	-.80	-1.25	-1.70
Farm price	$/cwt	-1.40	-2.10	-2.79
Retail price	$/cwt	-5.47	-8.18	-10.89
Pork				
Net returns	$/head	-1.29	-1.93	-2.57
Supply	Mil lbs	-16.27	-24.37	-32.44
Farm price	$/cwt	-1.19	-1.79	-2.38
Retail price	$/cwt	-3.78	-5.67	-7.57

beef, non-fed beef, pork, and sheep net returns all decrease.

Increased production at the cow-calf level had the effect on the vertically different levels of the beef industry of increasing the number of calves placed on feed and the number of non-fed cattle sold to slaughter. This increase in supply of beef, not being offset by a compensating increase in demand, caused the decrease in farm level and retail level prices.

The horizontal effects among competing livestock enterprises are shown in the substitution effect. As beef becomes less expensive at the retail level and consumers switch their meat purchases to beef, competing livestock enterprises such as sheep and pork experience a decrease in price levels which result in a commensurate decrease in the number supplied.

The aggregate effect of implementing cattle grazing in conjunction with pulp-sawtimber rotations would be a slightly lower internal rate of return on investments than was estimated for a single firm by the Lundgren, et al. studies (1983, 1984). However, the general conclusions reported in those studies should remain valid.

The implications for U.S. agricultural producers and consumers of implementing this technology (i.e., grazing cattle in conjunction with pulp-sawtimber rotations in the Southern Pine forests) are similar to those of most agricultural production technologies which increase efficiency of agricultural production. That is, society in general gains because consumers receive substantial benefits (more beef at lower prices in this case). This gain for consumers, however, is generally earned through losses in net revenues by producers. In this case, most livestock producers would experience farm level price reductions for their products of about 2.5 percent for beef and 1.5 percent for pork; assuming that the practice is implemented on 50 percent of the Southern Pine forests by 1990.

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The Interrelationships Among Management of Forested Range, Tree Pests, and Wildlife

William H. Sites

Abstract.--Notes that interrelationships between the management of forested range, tree pests, and wildlife have never been fully studied. Considers positive and negative impacts of forested range management on tree pests. Discusses the relationship between tree pests, cattle grazing, and wildlife populations which are generally localized.

INTRODUCTION

To the aspects of vegetation, grazing, and wildlife discussed at this workshop, I would like to add yet another consideration--the management implications of insects and diseases that attack trees. These are very important considerations for both range and timber management.

Many factors influence the spread and severity of insects and disease attacks on forest trees. Among them are weather, soil, past and present timber management practices, changes in plant species composition, and the previous land use. I will discuss a few management practices and how they affect pest populations.

My paper is not based on a designed study. Rather, it examines the practices of combined range and timber management for possible impacts on insects and diseases, and vice versa. We did conduct some general surveys to determine the relative distribution of some important pest problems.

The interrelationships among management of forested range and the many insects and diseases that attack trees have never been fully studied. However, many practices common in range and timber management are reflected in pest problems and are well know. I will discuss some of the more important ones here so that those managing for range and timber can optimize both resources.

THE INFLUENCE OF CATTLE MANAGEMENT PRACTICES ON TREE INSECT AND DISEASE POPULATIONS

Fire

As with other treatments, fire can have positive and negative impacts on pest incidence in trees. The use of fire to improve forage also controls brown-spot disease (caused by Scirrhia acicola [Dearn.] Sigg.) of longleaf pine (Pinus palustris Mill.) seedlings. Fire also offers good control of fruiting bodies of annosus root rot fungus (caused by Heterobasidion annosum [Fr.] Bret. [formerly Fomes annosus]) on the two most common hosts, loblolly (Pinus taeda L.) and slash (Pinus elliottii Engelm. var. elliottii) pines (Froelich and others 1978). While fire does not reduce the level of root disease already established in the stand, inoculum that would be otherwise available for infecting newly thinned stands is reduced. Similar indirect control of southern fusiform rust (caused by Cronartium quercuum [Berk.] Miyabe ex Shirai f. sp. fusiforme) with fire is accomplished by helping to control oak, the alternate host. In diseased stands, fire results in severe damage and mortality to galled stems in rust- infected stands and can also create unbleachable char (Belcher and others 1977), making wood fiber unsuitable for paper.

Southern pines are resistant to fire when they are mature, but seedlings and saplings can be killed outright. Furthermore, fire damage to stems and surface roots can invite attack by Ips beetles (Ips spp.) and the southern pine sawyer

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(Monochamus titillator [Fab.]) (Dixon and others 1984) or, in the case of older trees, can result in the development of root and butt rot caused by Polyporus schweinitzii Fr. The risks to the timber resource associated with fire are mainly from high-intensity fire or fire in regeneration. Low-intensity fires, typical of controlled burns, have more positive than negative impacts on pine stands beyond the sapling stage, and they certainly do improve forage quality.

Tree Spacing

The wide tree spacings that are suggested for improved forage production can also have positive and negative influences on tree diseases. Annosus root rot spreads rapidly in thinned slash, loblolly, and shortleaf pines (Pinus echinata Mill.) through root grafts and contacts between residual trees and stumps that become infected. This is particularly troublesome in plantations. Increasing distance between trees can reduce this means of spread (Kuhlman and others 1976).

Some debate exists over the relationship between tree spacing and damage from fusiform rust. Wider spacings may tend to increase damage from fusiform rust on loblolly and slash pines, because they result in poorer pruning of limbs with active galls that are close enough to the main stem to grow to and infect it. In addition, wider spacing reduces the number of stems per acre and is thought to increase the negative impact on yields from outright mortality and nonmerchantable, infected stems in moderately infected stands (Phelps and Czabator 1978). Belcher and others (1977), however, indicate that the close spacing results in significantly less growth of individual trees, smaller sizes of intermediate and end products, and delayed removal of rust-infected trees from the stand.

Depending on growth, stand characteristics, and level of infection, either of these theories may apply. Without a detailed analysis of the stand, considering growth, stand characteristics, and level of infection, it would be difficult to argue that wider spacing does or does not pose a conflict between grazing and timber production, unless the site is underutilized.

Fertilization and Cultivation

Pasture fertilization and cultivation can increase fusiform rust losses in slash pines (Balthis and Anderson 1944, Dinus and Schmidtling 1971). Although we normally think of increased tree vigor as retarding disease development, the reverse is actually true for fusiform rust on slash pines (Dinus and Schmidtling 1971, Hughes and Jackson 1962). Fertilized trees are much more prone to the disease, and trees that are cultivated as well as fertilized are the most rust sensitive (Dinus and Schmidtling 1971, Lewis and others 1972). Similar research tests on loblolly pines did not reveal similar increases in rust incidence (Dinus and Schmidtling 1971).

The effects of fertilization on root diseases are not known, but they are certainly less significant than for fusiform rust. For annosus root rot, soil texture and texture-related characteristics appear to be the most significant factor (Kuhlman and others 1976).

Fertilization of 92 slash pine families resulted in a significant increase in infection from the pitch canker fungus (Fusarium moniliforme Sheld. var. subglutinans Wollenw. and Reink.) (Lowarts and others 1985). Application of high rates of nitrogen and phosphorus fertilizer caused increased mortality in already infected trees (Fisher 1981).

The results of studies on the effects of fertilization on southern pine beetle attacks have been inconclusive (Haines and others 1976, Moore and Layman 1978). However, damage from the southern pine coneworm (Dioryctria amatella [Hulst]) was increased in fertilized slash pines (Hughes and Jackson 1962, Lewis and others 1983).

A significant conflict between grazing and tree management objectives arises with fertilization and cultivation of slash pines. Incidences of southern fusiform rust and southern pine coneworm in slash pine plantations are increased by these practices. In addition, since root rot fungi can enter via root wounds, any cultivation practice that causes root injury could result in an increase of these diseases.

Seedling and Site Selection

Planting stock should be selected carefully. To reduce disease potential, nursery stock should always be free of disease. This is particularly important in reducing losses to and limiting the spread of fusiform rust. To obtain the most resistant trees, seed source is very important. Livingston Parrish, Louisiana, has traditionally been considered an excellent source for loblolly pines resistant to fusiform rust. Slash pines from southern Mississippi also appear to have greater rust resistance (Wells and Lora 1974). Recently, Powers and Matthews[1] field tested loblolly pines from Livingston Parrish (LP), Angelina County, Texas (TX), and Clark County, Arkansas (AK). The TX and AK sources were more resistant than the LP.

Recent advances in screening for rust resistance in seeds from slash and loblolly seed orchards also provide a source of increased rust-resistant stock. Powers and Matthews found that loblolly and slash from a mixture of clones being considered for placement in a rust-resistant orchard also performed very well.

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[1] Powers, H.R., Jr. and F.R. Matthews. USDA Forest Service, Southeastern Forest Experiment Station, Athens, GA (unpublished)

Some pine species are more resistant than others to diseases and insects. Longleaf pines are more resistant than slash or loblolly pines to annosus root rot, southern fusiform rust, and bark beetles, and should be planted where site conditions are proper for it (Kuhlman and others 1976). Shortleaf pine (Pinus echinata Mill.) is also resistant to fusiform and should be considered, within its range, especially in high-hazard areas (Phelps and Czabator 1978). Although new information, as yet unpublished, will further delineate fusiform rust hazard zones, fusiform incidence maps were published by Phelps in 1973 for slash and loblolly pines. These and revisions of them should always be considered by managers when areas are planted. In high-hazard zones, resistant sources and species should be given a high priority.

For annosus root rot, low- and high-hazard sites can be identified (Kuhlman and others 1976). The sites with lowest hazard are in the Gulf and Atlantic Coastal Plains. These soils have poor internal drainage, high seasonal water tables, and subhorizons with a plastic consistency. A second low-hazard soil occurs in the rolling terrain of the upper Coastal Plains and Piedmont, where the soils are dry and have a heavy clay content within 12 inches of the surface.

High-hazard sites are generally those where soils are deep, sandy, and well drained (Kuhlman and others 1976); typical of the sandhills region. Timber management practices, particularly thinning practices, can be responsible for spread of annosus root rot.

Concentration Area

Cattle concentrate at feeding stations and ponds or other watering areas. The soil disturbance and compaction alone may reduce tree vigor. Root injuries provide infection courts for root disease fungi, such as H. annosum. Low vigor or injured trees may also attract southern pine beetle, which can subsequently spread to other areas that have not been directly influenced by livestock.

THE INFLUENCE OF TIMBER MANAGEMENT PRACTICES ON INSECT AND DISEASE POPULATIONS

In addition to fire and fertilizer application, which have already been discussed, other practices designed to improve tree growth can influence insect and disease risks.

Thinning

Thinning in either plantations or natural stands improves tree growth and increases forage production. Thinning generally reduces disease and insect impacts through salvage removal of diseased stems, as in the case of fusiform rust. Since thinning increases vigor of the trees that are left, it also reduces the threat from pests like southern pine beetle, if the residuals are not damaged by soil compaction or logging injuries.

However, damage by annosus root rot is often increased by thinning (Powers and Verrall 1962, Rishbeth 1951). If there is a source of spores, the fungus can spread to fresh stumps and then to live trees (Hodges 1969). Spores landing on freshly cut stump surfaces germinate and colonize the stump and root system. They can then infect surrounding trees via root grafts and contacts. Several surrounding trees may contact roots of one infected stump and be infected by it. Thus, wider spacings to reduce thinnings would benefit both disease management and forage production.

In addition to spacing, annosus root rot can be controlled by: 1) thinning from April to August south of the 34th parallel where air and stump temperatures may be hot enough to kill spores; 2) applying borax to the stump surface immediately after felling, if there is no annosus in the stand; or 3) applying a spore suspension of the competing fungus, Phlebia gigantea [Fr.] Donk., to the stump surfaces. This fungus competes with H. annosum, decaying the stump before H. annosum can utilize it for a food base. It should be noted that thinning during the hottest part of the year has some drawbacks. Thinning operations typically run for extended periods of time, and weather conditions are not always so extreme to effectively control annosus spores. Further, bark beetles may be attracted to damaged trees and slash in larger numbers at this time of year, thus increasing the risk of outbreaks. These trade-offs make the other annosus control options more attractive.

Rotations

Short rotations of 25 years (Byrd and others 1984) will reduce the impact from most insects and diseases, particularly annosus root rot that can be made worse by thinning. Trees grow rapidly through age 25 and suffer less than older trees from attack by bark beetles or root rots.

THE DIRECT INFLUENCE OF CATTLE ON FOREST INSECTS AND DISEASES

A key question is whether cattle directly influence insect and disease attacks on trees. Cattle are, of course, not susceptible to tree diseases, and trees are not subject to cattle diseases. The question is, therefore, whether cattle do things that influence the attack of insects and diseases on trees or that influence their spread from tree to tree.

Some noticeable trends have emerged during other surveys. In Mississippi and Georgia, two loblolly pine stands growing on low-hazard sites were severely infected with H. annosum. Fruiting structures of the fungus were numerous and grew from injured surface roots. In both locations, the injuries closely resembled those made by cattle. Basal and surface root wounds are very prone to infection by this fungus, though freshly cut stump surfaces are considered the primary method by which stands become infected.

In Flagler and Volusia Counties in Florida, slash pine saplings were infected with the pitch canker fungus at places where limbs were broken by grazing cattle[1]. Broken lateral branches provide infection courts for this fungus.

Where annosus root rot was observed, the cattle had been concentrated and root injuries were common. More dispersed grazing would probably result in less injury and subsequent infection. Thus, I foresee a problem with H. annosum only in places where cattle are concentrated, such as at supplemental feed stations or watering areas. In the case of pitch canker, I believe that damage or injury potential decreases as the trees grow and the number of lower limbs decline.

THE INFLUENCE OF FORESTS INSECTS AND DISEASES ON OTHER VEGETATION, CATTLE AND WILDLIFE

The insects and diseases that attack trees do not attack other vegetation. Their influence on lesser vegetation is largely on the creation of openings, resulting from tree mortality (Maine and others 1980). The size and distribution of these openings are the most important factors. Edge is created, snags are made available for cavity nesting birds and animals, understory plants that can be used by cattle and wildlife are stimulated, and in the case of insect pests like bark beetles, the pest is a food supply itself.

Southern pine beetle outbreaks result in contiguous openings that can encompass a few to several hundred acres, while annosus root rot centers are smaller. Pitch canker disease, when epidemic, also can create small openings of several trees, but these are usually even smaller and less abundant than those caused by annosus root rot. Openings created by southern pine beetle have the greatest potential impact on grazing by increasing forage. However, Leuschner and Maine (1980) reported that a study conducted on the Trinity District of the Davy Crockett National Forest revealed that, in general, openings caused by southern pine beetle are of little benefit to cattle grazing.

Fusiform rust is randomly distributed in stands and resultant mortality creates single-tree openings that alter spacial relationships of trees only slightly. Significant impacts from rust are expected only when infection levels and rust associated mortality are extremely high. Epidemics of any of these pests effectively eliminate timber management opportunities through mortality, reduced volume growth, or product-degrading deformities.

In the best known case of an interaction between a tree disease and wildlife, the heart rot fungus, Phellinus pini (Thore: Fr.) Pilat [formerly Fomes pini (Thore)], causes heartwood decay that softens the wood for easier removal by the red-cockaded woodpecker in nest cavity preparation (Hooper and others 1980). Phellinus pini causes extensive decay only in pines that are approaching maturity or are fully mature. Since harvesting has reduced this class of growing stock, many federal, state, and private organizations have invoked protection programs to retain adequate nesting.

Tree insects and diseases have other influences on wildlife. Southern pine beetle itself is food for woodpeckers (Kroll and others 1980) Other nongame bird species and some predators may enjoy improved habitat and food as a result of southern pine beetle. Small mammal and finch populations increase in newly cut pine stands (Edwards 1978). This successional change would be similar to that caused by southern pine beetle-induced mortality.

Changes in turkey habitat, as a result of southern pine beetle, are regarded as negligible (Leuschner 1980). The impacts on squirrels are also low in pure pine stands, but southern pine beetle can have a positive impact on white-tailed deer populations (Maine and others 1980). Those authors estimated that 1 acre of a southern pine beetle spot yielded 14.5 additional deer-days of food. The positive impact also included increased woodland edge. Leuschner (1980) also estimates that there is a positive influence on quail habitat with increased edge.

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[1] L. David Dwinell, Pathologist, USDA Forest Service, Southeastern Forest Experiment Station, Athens, GA (personal communication)

The effects on fish, small mammals (mice, shrews, etc.), and large mammals (opossums, skunks, etc.) are poorly understood. Leuschner (1980) states that a "negligible net impact is assumed, based again on lack of evidence rather than evidence of no effect."

The impact of tree diseases on other vegetation and wildlife is even less understood. Diseases like fusiform rust kill individual trees. Many trees in a stand may be affected, but not in centers like those created by southern pine beetle or annosus root rot. Thus, the increased open area and edge effect of fusiform rust mortality are difficult to assess. Effects may be significant only where tree losses are very high.

Annosus root rot on the other hand does affect trees in groups due to its underground spread via root grafts and contacts. The potential for impacts on ground cover and wildlife should be similar to those of small southern pine beetle spots.

SURVEY OF SOUTHERN EVALUATION PROJECT PLOTS

In 1978 and 1979, general insect and disease surveys were conducted in three of the five plots in the Southern Evaluation Project. They included Texas, Mississippi, and Florida sites. In addition, a plot in Louisiana was partially surveyed. The surveys consisted of 1-mile transects begun at points along the perimeter. A record was kept of the insects and diseases observed. Pests specifically targeted in the survey were Ips engraver beetles, southern pine beetle, and black turpentine beetle (Dendroctonus terebrans Oliv.); annosus root rot, fusiform rust, pitch canker disease, and heart rot (caused by P. pini). This list includes the major pests that affect managed pine timber. At the time, a more detailed survey was not possible.

By far the most significant problem observed was fusiform rust. It was present in all locations where loblolly and slash pines occurred. In only one case, in Mississippi, did the root rot fungus H. annosum occur.

After grazing treatments have been imposed for sufficient time to permit pest problems to develop, new surveys probably should be considered. If disease problems develop, the possible relationships to grazing should be analyzed.

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Watersheds, Socioeconomics, and Forest Pests Discussion

Question

For continuity at the local level, would there be merit in keeping a key person, such as a silviculturist or other resource person, on the District for longer time periods?

Response

The Forest Service presently has longer tenure (3 to 5 years) for district personnel than in the past mainly for two reasons: (1) economic effects on the employee and (2) continuity in the job. There is also a need to balance the need for continuity with the need for career development. As the employee moves to higher levels of management, it is important to have experienced different situations; consequently, everyone cannot remain in a location.

Question

Did the economic projections for livestock production pertain to all forested land in the South or just to National Forest lands?

Response

The study was designed for implementation on all suitable forested land (pine types) in the South and included both public and private lands.

Question

Did the study consider moving cow herds from pasture to the forest-range or were the herds increased? Was the economic benefit reflecting lower production or lower cost of production?

Response

The cow herd size was increased on forest-range irrespective of pasture herd movements; however, this could be accomplished by moving animals from pasture to forest-range to reduce cattle numbers in pasture. The model assumption using forest-range resulted in reductions in cost of production. A shift from pasture to forest-range would reduce cost but not increase beef supply, while additional cows on the forest-range should increase the beef supply, which could further aggrevate market surpluses.

Question

Would there be a regional shift in cow herds from West to East?

Response

A shift would occur only if cost reductions were great enough; however, the maximum cost reductions for the U. S. (based on the model) would be too small to cause regional shifts.

Question

Did the cost reductions include going through the feedlot?

Response

The reduction was realized because of decreases in the cow-calf production costs prior to the feedlot.

Question

Was the cost of additional management (such as fencing) included in the economic analysis?

Response

The cost for facilities and operation included fences, corrals, water, supplemental feeds, and other expenses in using the forest-range resource.

Question

Was the cost per AUM computed for the forest-range? Could this information provide some information regarding the controversy over grazing fees on National Forest and private lands?

Response

The cost per animal could be calculated from the basic data but would have to be tied back to specifi situations for determining grazing fees. The present economic model was not designed for that purpose.

Comments

It is suggested that sediment from small plots be reported in grams or kg per m^2 rather than kg/ha. We are talking about soil movement from small plots and not necessarily erosion. Erosion reflects impoverishment of the site and what it does to water quality. Water quality should be in terms of sediment concentration and not yields that normalizes the data. For example, a base rate for loblolly pine from East Texas through the Piedmont is about 14 lb/acre-inch runoff, which gives wide rates of sediment production in tons/acre depending on the year and runoff.

Response

Similar small plot data have been reported for 15 years in lb/acre or kg/ha. It is not that important whether it is reported in lb/acre or g/m^2. It is a relative rate and basically used as an index and not as a loss.

For comparisons, sediment yields off agricultural lands (which are measured in tons/acre) far exceed the small amounts from forestry or grazing of woodlands. For example, on large watersheds in northern Florida (Bradford Forest), the sediment, water, and nutrient yields off the actual watersheds were found to be minor from forest regeneration practices.

APPENDIXES

APPENDIX I SOUTHERN EVALUATION PROJECT PUBLICATIONS

Anderson, M. E. 1981. Song dialects and syllable structure as related to the environment of three east Texas cardinal populations. Nacogdoches, TX: Stephen F. Austin State University; 77 p. M.S. thesis.

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APPENDIX II SOUTHERN EVALUATION PROJECT PRESENTATIONS

The following is a list of presentations made at various meetings.

Anderson, M. E.; Conner, R. N.
Dialects and syllable structure of three East Texas cardinal populations. Annual meeting Wilson Ornithological Society 1982 May; Blacksburg, VA.

Byrd, N. A.
Private land grazing on forest lands. Annual meeting of Southern Section, Society for Range Management; 1981 December 11; Gulfport, MS.

Conner, R. N.; Anderson, M. E.; Dickson, J. G.
Relationships among cardinal (*Cardinalis cardinalis*) territory size, vegetation, song, and nesting success. Annual meeting American Ornithologists Union, 1982 October; Chicago, IL.

Conner, R. N.; Dickson, J. G.; Williamson, J. H.
Comparisons of two census techniques and mist net captures. Annual meeting Wilson Ornithological Society, 1982 May; Blacksburg, VA.

Dobrowolski, J. P.; Blackburn, W. H.; Grelen, H. E.
Infiltration rates and water quality of longleaf pine/bluestem range following 22 years of seasonal burning. 37th annual meeting of the Society for Range Management; 1984 February 12-17; Rapid City, SD. Denver, CO: Society for Range Management.

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Pearson, H. A.
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APPENDIX III SOUTHERN EVALUATION PROJECT REPORTS

Texas: Loblolly-Shortleaf Pine Type

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Smeins, F. E.; Hinton, J. Z. 1981. Vegetation inventory in the loblolly- shortleaf pine type, Angelina National Forest. College Station, TX: Texas A & M University. Progress Report. 142 p.	CA-19-304 1701-3.16
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DeHaven, M.; Blackburn, W. H. 1980. Assessment of nonpoint source pollution from intensive forest practices in East Texas. College Station, TX: Texas A & M University. Progress Report. 37 p.	CA-19-341 1701-3.21 -1.121 -1.110 4201-1.121
Hunter, T. K.; Blackburn, W. H.; Knight, R. Weichert, A. T. 1981. Assessment of non-point source pollution from livestock grazing on intensive managed forest in the Southeast. College Station, TX: Texas A & M University. Progress Report. 57 p.	CA-19-341 1701-3.21 -1.121 -1.110 4201-1.121
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Texas: Loblolly-Shortleaf Pine Type (continued)

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Fleet, R. R. 1982. Effect of multiple-use forest range management on small animal population. Nacogdoches, TX: Stephen F. Austin State University. Final Report. 155 p.	CA-19-300 1701-4.9
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Roath, L. R; Pearson, H. A. 1986. Forage utilization techniques. College Station, TX: Texas A & M University. Final Report. 41 p.	CA-19-373 1701-1.770

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Noble, R. E.; Reed, D. P. 1981. Vegetation inventory in loblolly-shortleaf pine type near Dry Prong, LA. Baton Rouge, LA: Louisiana State University. Final Report. 257 p.	CA-19-305 1701-3.17 PO#40-7B82-0-22211
Williams, K. L. 1982. Inventory of the species, diversity, and numbers of amphibians and reptiles on selected loblolly-shortleaf pine and longleaf-slash pine stands (pre-treatment phase). Natchitoches, LA: Northwestern State University. Final Report. 31 p.	CA-19-332 1701-4.12
Hamilton, R. B.; Ellsworth, S. W.; Smith, J. C.; Lester, G. 1983. Bird and mammal evaluations on the Louisiana loblolly-shortleaf pine range project. Baton Rouge, LA: Louisiana State University. Final Report. 3 p.	CA-19-343 1701-4.14

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Butler, L. 1979. Soil survey, Vernon, Kisatchie National Forest. Soil Conservation Service. Soil Survey Report. 26 p.	CA-19-322
Pearson, H. A.; Grelen, H. E.; Rollins, D. A.; Parresol, B. R. 1984. Soil vegetation correlation in the longleaf pine type of Louisiana. Alexandria, LA: Southern Forest Experiment Station. Final Report. 75 p.	PO#43-7B82-1-10628 1701-3.20
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Mississippi: Longleaf-Slash Pine Type

Davis, R. E. 1979. Soil survey of designated portion of DeSoto National Forest in Stone County, Mississippi. USDA Soil Conservation Service. Soil Survey Report. 49 p.	CA-19-321
Hurst, G. A.; Stewart, A. W.; Pearson, H. A. 1981. An inventory of vegetation in longleaf-slash pine type in Mississippi. Mississippi State, MS: Mississippi State University. Final Report. 122 p.	CA-19-303 1701-3.18
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Wolfe, J. L.; Lohoefener, R. R. 1980. Inventory of amphibians and reptiles on two range units of the range evaluation project, DeSota National Forest. Waveland, MS: Southern Ecology Laboratory. Final Report. 22 p.	PO#40-7B82- 9-10484 1701-4.17
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Lohoefener, R. R. 1982. Results of the herpetofauna census, Southern Evaluation Project, DeSoto National Forest, Mississippi. Mississippi State, MS: Mississippi State University. Final Report. 41 p.	PO#40-7B82- 2-22248 1701-1.350
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Wolfe, J. L.; Lohoefener, R. R. 1981. Pretreatment assessment of fish diversity and relative abundance of four range units of the Southern Evaluation Project, DeSoto National Forest, Mississippi. Waveland, MS: Southern Ecology Laboratory. Final Report. 18 p.	PO#40-7B82- 1-22521
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Tanner, G. W.; Terry, W. S. 1982. Inventory of nutritional quality of major dietary components of domestic herbivores on the Apalachicola National Forest, Florida. Gainesville, FL: University of Florida. Final Report. 48 p.	CA-19-342 1701-3.23
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/ Study numbers refer to cooperative agreement (CA), purchase order (PO), project (1701, 4201) or SEP designations.

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The results of 43 research projects, which evaluate the flora, fauna, watersheds, socioeconomics, and forest pests located on the southern National Forests, were presented and discussed in 4 major categories: Management Outlook and Evaluation, Loblolly-Shortleaf Pine Type, Longleaf-Slash Pine Type, and Watersheds, Socioeconomics, and Forest Pests.

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